Universidade Técnica de Lisboa
Faculdade de Motricidade Humana

# *Environment perception and child safety*

Dissertação apresentada com vista à obtenção do grau de Doutor
em Motricidade Humana na especialidade de Ciências da Motricidade

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**2010**

FCT Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR Portugal

The work presented in this dissertation was supported by the Foundation for Science and Technology (Portugal), program PIDDAC, grant SFRH/BD/39261/2007 awarded to Rita Cordovil de Matos.

The studies that investigated the climbing affordances of safety barriers for children had financial support from ANEC – The European Consumer Voice in Standardization: grant ANEC-ML-2007-0069.

**Agradecimentos**

Gostaria de expressar o meu agradecimento a várias pessoas cujo envolvimento e interesse foram cruciais não só para a elaboração desta tese como também para o meu crescimento profissional e pessoal:

- Ao João Barreiros, pelo apoio constante e por ser um dos principais culpados pela minha eterna curiosidade científica.
- A todos os colegas e amigos que me foram acompanhando ao longo deste percurso, sempre disponíveis para discutir ideias e dar sugestões. Um agradecimento especial ao Duarte Araújo e ao Pedro Passos pelas discussões produtivas e encorajamento constante.
- Aos colegas e amigos que ajudaram nas recolhas de dados: Tiago Ramos, Filomena Vieira, Rita Alexandre, Goreti Patrocínio, Sofia Fonseca, Eduarda Veloso, Carlos Santos, Dora Ralão e Ana Mateus.
- Às crianças, pais, professoras, auxiliares e outros participantes nos estudos.
- À “APSI”, ao “Centro Infantil O Palhaço”, à “Torre” e ao “Solplay Health Club”.
- Aos pais e família pelo apoio incondicional e por serem também culpados pelo prazer que sinto em continuar a estudar.
- Ao Tiago, ao Diogo e à Joana que viveram todas as alegrias e angústias de perto e para quem as palavras não chegam para agradecer... obrigada por tudo.

**Abstract**

This dissertation addresses some aspects of child safety grounded on an ecological psychology framework. The investigation of risk affordances was nested in children's behavior in specific environments, and not merely on a strict dimension-morphology ground. Reaching and climbing skills were analyzed for their relevance to child safety. Adult's perception of children's affordances was repeatedly investigated in reaching tasks indicating that adult's can make reasonable accurate predictions about children's action limits, but estimation errors and error tendency depend upon the characteristics of the observer, of the child, and of the task. Perceptual experience seems to play an important role in caregivers' attunement to the information that specifies children's affordances. One single observation of the child's action was enough to significantly reduce estimation error, particularly in least accurate perceivers. One chapter replicated a common drowning condition: children trying to retrieve a toy in the water from the swimming pool deck. Different action modes were used but most children sat and fell in while attempting to grasp beyond their reaching limits. Two studies investigated the climbing affordances of safety barriers for children, pointing to an easy and fast crossing of common panel and horizontal bar barriers. Results also indicated that safety devices must consider body dimensions and motor skill. This thesis contributes to a better understanding of children's behavior in potentially risky environments, as well as an insight into the adults' perception of children's action limits.

Keywords: affordances; perception; child safety; reaching; climbing; risk; supervision; morphology; action; attunement.

**Resumo**

A presente dissertação aborda aspectos da segurança infantil, tendo como base teórica a psicologia ecológica. Diferentes *affordances* de risco foram analisadas tendo em conta não só os aspectos morfológicos das crianças, mas também os seus comportamentos em envolvimentos específicos. Foram estudadas as acções de alcançar e trepar devido à sua relevância em termos de segurança infantil. A percepção que os adultos têm das *affordances* das crianças foi repetidamente investigada em tarefas de alcançabilidade, indicando que os adultos conseguem prever os limites de acção das crianças com uma precisão razoável, e que os erros de estimativa e a tendência de erro dependem de características do observador, da criança e da tarefa. A experiência perceptiva parece ter um papel importante no ajustamento à informação que especifica as *affordances* das crianças. A observação de crianças a realizar uma única vez uma acção reduz significativamente os erros de estimativa, particularmente quando as estimativas iniciais são pouco precisas. Num dos capítulos replicámos uma situação comum de afogamento: as crianças, na borda da piscina, tentaram alcançar um brinquedo que se encontrava na água. As crianças utilizaram diferentes modos de acção, mas a maioria sentou-se e caiu na água quando o brinquedo estava para além do seu limite de alcançabilidade. A percepção dos pais foi também estudada. Dois estudos analisaram as *affordances* para as crianças de barreiras de segurança, indicando que as barreiras mais comuns de grades horizontais e de painel são fácil e rapidamente transpostas. Os resultados também indicam que barreiras de protecção adequadas devem ter em conta as dimensões corporais e a habilidade motora das crianças. Esta tese contribui para uma melhor compreensão dos comportamentos das crianças em envolvimentos de risco potencial, assim como para o conhecimento da percepção que os adultos têm dos limites de acção das crianças.

Palavras-chave: *affordances*; percepção; segurança infantil; alcançar; trepar; risco; supervisão; morfologia; acção; *attunement*.

**Publications**

Parts of this thesis have been published, accepted for publication, or submitted for publication:

Cordovil, R., Barreiros, B., & Araújo, D. (under review). Constrain risk affordances, but don't think you can remove them: an ecological stance for risk and safe behaviors in children. (Submitted to *Ecological Psychology*).

Cordovil, R., & Barreiros, B. (under review) Egocentric or allocentric frameworks for the evaluation of other people's reachability. (*Human Movement Science*).

Cordovil, R., & Barreiros, B. (2010). Adults' perception of children's height and reaching capability, *Acta Psychologica, 135*(1)*,* 24-29.

Cordovil, R., Barreiros, B., & Santos, C. (under review).Retrieving a toy from a swimming pool: a possible drowning cause. (Submitted to *Journal of Safety Research*).

Cordovil, R., Barreiros, J., Vieira, F., & Neto, C. (2009). The efficacy of safety barriers for children: absolute efficacy, time to cross and action modes in children between 19 and 75 months. *International Journal of Injury Control and Safety Promotion, 16*(3), 143 - 151.

Cordovil, R., Barreiros, B., & Vieira, F. (under review) Crossing safety barriers: influence of children's morphological and functional variables. (Submitted to *Accident Analysis and Prevention*).

Some parts of this thesis and additional exploration of data have been or will be presented in congresses and published in abstract books and in special issues of scientific journals.

*Abstracts in international scientific periodicals with referees:*

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*Communications in proceedings with refereeing:*

Cordovil, R, Barreiros, J., Neto, C., & Araújo, D. (2008). Play, environment and affordances. In C. Chow & T. Wong (Eds.), Play in a changing world - *Book of abstracts of the 17th International Play Association World Conference* (pp. 85). Hong Kong, January 2008.

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Tables were numbered following chapter number.

# 1. Prolegomenon

### 1.1. Introduction

Traditionally, strategies to address child safety issues have focused on the environment, trying to determine what “risk environments” are, and on the individual, trying to determine who the “risk children” are. In the present thesis, some aspects of child safety will be addressed based on an ecological psychology approach. According to our theoretical framework, we consider risk not to be a property of the environment or of the individual, but a relational concept that emerges from the interaction of a specific individual in a given environment. Therefore, the research on child safety issues should be nested in children’s behavior in specific environments, and not merely on a strict dimension-morphology ground.

The United Nations Convention on the Rights of the Child (1989) underlines the social responsibility to protect children, stating that children have the right to the highest attainable level of health, and the right to a safe environment. However, the problem of child safety is somewhat complex to deal with for two main reasons:

- Children are not just “small adults”, they have different interests, different levels of maturity, and their action capabilities are many and difficult to characterize, being substantially different from the adult’s which are usually presented as a reference.
- The environments where the children have to be in are usually designed for grown up organisms, with small adaptations to the children’s characteristics. Very often, those environments are not designed according to children’s choices or even their parent’s choices. The socio-economic conditions children live in influence largely the safety of their surrounding environment.

Environment and organism introduce singularity into the problem of children’s safety and have been the focus of most analysis concerning child safety issues. This thesis proposes an ecological approach to risk and emphasizes the importance of caregivers in selectively structuring environments for children.

### 1.2. Thesis general and specific goals

This thesis aims to contribute to a better understanding of children’s behavior in potentially risky environments, as well as an insight into the adults’ perception of children’s action limits.

Adult's supervision has been considered an essential determinant of children's safety (Morrongiello, 2005; Saluja et al., 2004) and the adult's estimation of a child's affordances is frequent in daily life situations, since parents and caregivers share the responsibility to manage the environments the children move in. However, investigation concerning the adult's perception of children's affordances is rather scarce. In the present dissertation, we addressed not only the issue of the adult's perception of children's action capabilities but also the possibility of improving that perception by watching children's action. Theoretically, this is a matter of perceiving affordances in the others.

Reaching and climbing skills were analyzed for their relevance to child safety, because these actions allow children to gain access to dangerous places or to dangerous objects, being related to a number of child injuries (e.g., drowning, falls, burns and scalds and poisonings).

Reaching is an action that emerges quite early in human development. By 4 to 5 months most infants make efforts to voluntarily reach and grasp objects. The use of the hands enables children to explore the environment in a new way. At the onset of walking the possibilities for exploration increase dramatically: a limited support basis and a vertical structured world will replace the former safe ground world. Hands can operate with greater autonomy, objects that were previously unreachable became accessible, and curiosity leads children's exploration. Reaching objects in high places becomes a challenge and that increases the potential for accidents. Burn, scald or poisoning accidents are frequently related to the child's inner urge for exploration associated with an increased reaching capability. A study of hospital emergency department–treated injuries to children aged 5 years and younger (Drago, 2005) identified one prevalent pattern for thermal burn accidents: "coming in contact with (usually touching) hot cookware"; and two prevalent patterns for scald accidents: "reached up and pulled down pot from stove or other elevated surface" and "grabbed, overturned, or spilled pot onto self". Poisonings are also frequently associated with the children's reaching capability, the world report on child injury prevention refers that "the most obvious risk factor for ingestion of a substance is its presence in the domestic environment, within reach of the child" (Peden et al., 2008, p.132). Reaching might also be related to drowning accidents in some specific situations. For instance, the Centers for Disease Control and Prevention (CDC, 2004) emphasize that the presence of toys in the pool and surrounding area may encourage children to enter the pool area or lean over the pool to reach the toys and potentially fall in.

Climbing is a natural movement that broadens children's exploration capabilities. Children have an inner urge to climb and improve their motor skills. From the moment toddlers start to pull themselves up they start practicing their climbing skills, and by the age of 6 most children have the skills to climb as an adult. Children often use climbing tasks as a challenge, as they promote development and skill improvement. They will climb anything that attracts them, such as steep slopes, trees, or even guards or barriers designed to restrict their access to risk environments. Climbing safety barriers might lead to falling or drowning accidents. Children's age is related to the nature of fall accidents. In what concerns falls from heights, pre-school children usually fall from windows and older children fall from other dangerous areas, such as rooftops and fire escapes (Bull et al., 2001; Sieben, Leavitt, & French, 1971). Effective window guars, roof railings and stair gates are recommended to prevent falls from heights (Peden et al., 2008). Drowning is the second leading cause of unintentional death worldwide (Peden et al., 2008) and the most vulnerable are 1 to 4-year-old children (Peden et al., 2008; Peden & McGee, 2003; Vincenten, 2004). In high income countries children in this age group are most likely to drown in swimming pools (Brenner, 2003; Quan, Gore, Wentz, Allen, & Novack, 1989). Pool fencing has been recommended as effective strategy to decrease risk of drowning.

A better understanding of children's risk affordances might help caregivers and other professionals to structure children's environments in a way that promotes children's safe exploration without compromising their opportunities for exploring and learning.

**1.3. Structure of the thesis**

The present thesis starts with a presentation of its theoretical framework, proposing the definition of "risk affordances" (chapter 2). This definition considers risk to be a relational property between the individual and the environment. If the individual is a child, the caregivers' actions are also of fundamental importance, since caregivers not only supervise children's behaviors, but they also structure the environments where children move in. A better understanding of children's and caregiver's actions in different environments is imperative to ensure the safety of children as a fundamental human right.

As a starting point to select which risk situations should be studied in the present work, we focused on the analysis of statistic data on children's injuries. Most statistics on children's accidents focus only on child mortality (e.g., Vincenten, 2004). Although the analysis of mortality is of unquestionable importance it is not enough, since death is only the top of the iceberg when we look into children's accidents. Data from the Consumer Safety Institute (*Deaths and Injuries due to Accidents and Violence in the Netherlands 1998-1999*, 2000) indicated that in The Netherlands for every child death that occurred just from a home and leisure injury (i.e., not resulting from road traffic or occupational accidents), another 160 children were admitted to a hospital with a severe traumatic injury, and another 200 children were treated at the accident and emergency departments. Furthermore, it's difficult to determine how many children visited pediatricians or health clinics for reasons of less severe injuries, and how many children had accidents in which, luckily, it was not necessary to go to a health care facility.

According to the first World Report on Child Injury Prevention (Peden et al., 2008) the leading causes of injury deaths in the world are: road traffic injuries, drowning, burns, falls and poisonings.

Considering this group of causes, we chose not to address the questions of road accidents since in the road environment children are frequently passive subjects, whose safety is largely dependent on the actions of adults. The remaining causes are largely dependent on children's actions in specific environments. For this reason, we analyzed some children's actions that are related to different types of accidents, namely:

- Vertical reaching, an action that allows children to access objects in high places (e.g., a hot pot in a stove or a dangerous object on a shelf), being related to burns and scalds or other type of domestic accidents, such as poisonings or falls of objects on children. Chapters 4, 5 and 6 address the issues of vertical reaching. These chapters focus not only on children's action capabilities but also on adult's perception of those capabilities, and on the possibility of improving adults' perception by watching children in action. Adult's perception of children's capabilities is fundamental since it has an important influence not only in the way that adult's organize children's environments, but also in the efficacy of their supervision.
- Horizontal reaching, an action that usually is not related to child's accidents except in some specific environments (e.g., reaching a toy from a swimming pool deck), being related to drowning. Chapter 7 analyses the specific situation of retrieving a toy from a swimming pool deck, focusing not only on children's behaviors but also on their parents estimations.
- Climbing, an action that allows children's access to water environments (e.g., fenced swimming pools) or to places with different height levels (e.g., balconies or steep slopes), being related to drowning and falls. Chapters 8 and 9 of this thesis focus on children's climbing skills while trying to pass safety barriers. These chapters have a more applicative nature since they were part of a project which intended to evaluate different safety barriers in order to argue for appropriate requirements in standards.

The final chapter of this thesis presents a synopsis of the main findings of the preceding chapters, provides a more detailed explanation of some methodological options of the studies, discusses the theoretical and practical implications of the present thesis, and suggests topics for further research, before presenting the general conclusion of this dissertation.

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# 2. Constrain risk affordances, but don't think you can remove them: an ecological stance for risk and safe behaviors in children

### 2.1. Abstract

Unintentional injuries are a major cause of death and disability among children. Strategies to address child safety issues have focused on the environment, trying to determine what "risk environments" are, and on the individual, trying to determine who the "risk children" are. In this article, grounded on an ecological psychology framework, we suggest a convergent approach to this problem, which considers risk a relational concept, proposing the existence of risk affordances focused on the interaction between children and the environments they move in. We emphasize the role of caregivers in constraining risk affordances by supervising children's behaviors and by structuring the environments in ways that may inhibit the occurrence of child unintentional injuries.

### 2.2. Introduction

According to the World Report on Child Injury prevention (Peden et al., 2008), every day around the world more than 2000 families lose a child due to unintentional injury. Unintentional injuries are also a major cause of disabilities among children, with a major impact on their own lives as well as the lives of their families. The United Nations Convention on the Rights of the Child (*Convention on the Rights of the Child*, 1989) states that children have the right to the highest attainable level of health, and the right to a safe environment. However, the problem of child security is somewhat complex to deal with for two main reasons. First, the environments where the children move in are frequently designed for grown up organisms with small adaptations to the children's characteristics. Second, the child action capabilities are many and difficult to characterize, being substantially different from the adult's which are usually presented as a reference. These factors interact with the inherent variability of children's behavior, resulting in unpredictable accidents and injuries.

Environment and organism introduce singularity into the problem of children's safety and have been the focus of most analysis concerning child safety issues. In this article, we first present the contributions of previous research to the identification of "risk environments" and "risk children". Then, we propose an ecological approach to risk, which considers risk as a particular kind of affordance. This approach will be delimited to risk affordances in children. Finally, we emphasize the importance of caregivers in selectively structuring environments for children, in order to constrain risk affordances without compromising their opportunities for exploring and learning.

**2.3. “Risk environments”**

Traditionally, risk is related to the expected losses that can be caused by an event, in association with the probability of occurrence of this event (*ISO/IEC Guide 50, Safety aspects - guidelines for child safety*, 2002). Accordingly, the analysis of risk environments has been based on statistics of children’s injuries in different environments. The World Report on Child Injury prevention (Peden et al., 2008) identifies five leading causes of children’s unintentional injuries around the world: road traffic injuries, drowning, burns, falls and poisonings. Accident prevention analysis have focused on environments with features like roads (related with traffic injuries), water surfaces (related with drowning), objects or places with high temperatures (related with burns and scalds), places with different height levels (related with falls), and access to toxic substances (related with poisoning). Some environmental characteristics such as family related variables (e.g., poverty), novelty and variation in daily routines, lack of physical constraints, and lapses in supervision are known to increase the risk of accidents (Neto et al., 2008). Some groups of unintentional injuries also have seasonal trends. For instance falls from heights tend to cluster in the summer months presumably because windows tend to be open (Bull et al., 2001), and they also peak around meal times when supervision might be more careless (Istre et al., 2003). The strategy of identifying risk environments is undoubtedly very important, since it allows the delimitation and deeper analysis of places where the probability of accidents with children is higher. However, the analysis of this “risk environments” should not be separated from the analysis of how the individuals act in these environments. The “risk” is not a property of a specific environment, but it emerges from the interaction between a specific individual with a specific environmental condition.

**2.4. “Risk children”**

The concern for the safety of young children led to a growing amount of research related to individual constraints that determine risk-taking behavior. Variables such as age, gender, socioeconomic factors, and temperament have been examined as possible causal factors associated with children engaging in unsafe behaviors (Peden et al., 2008). The “risk age” is directly dependent on the type of injury, for instance, traffic injuries are the leading cause of death among 15-19-year-olds, whereas drowning shows the highest rate in the 0-4 year-age bracket (Peden et al., 2008). Boys tend to have more severe and more frequent injuries than girls (Crawley, 1996). Children in low-income and middle-income countries, especially poor children, have more frequent unintentional injuries (Delgado et al., 2002; Hyder et al., 2008). Temperamental characteristics, such as high levels of gross motor activity, have also been related with accidental injuries (Plumert & Schwebel, 1997). In fact, some individual characteristics seem to be associated to the risk of suffering an unintentional injury, but we argue next that even that is the result of the interaction between the individual and the environment.

### 2.5. An ecological approach to "risk"

From a child security perspective, the analysis of the different interacting constraints is of fundamental importance. For example: changes in body dimensions, such as an increase in height might allow the child to reach objects that were previously unreachable; changes in climate conditions, such as change from sunny weather to rain, will make the task of walking across a tile floor, previously dry but now wet, more difficult; and a change in a slope, like a steeper inclination, may drive the walking mode from walking to sliding. It is plausible that a part of the "random" nature of children's accidents relies on the changing nature of constraints during infancy and childhood, and the rate of change over time. There is some support to the hypothesis that the probability of accidents increases in periods of fast body changes or in early stages of motor acquisitions. Studies on "retuning" (Hirose & Nishio, 2001; Mark, 1987; Mark, Balliett, Craver, Douglas, & Fox, 1990) have demonstrated that after altering participant's body scales (e.g., by asking them to wear blocks on their feet), the initial overestimation or underestimation judgments gradually become more accurate. This retuning occurs if participants are allowed to engage in information-gathering activity that may or may not be of the same nature of the task they are asked to judge. Periods of fast body changes imply a process of adaptation to new action capabilities during which retuning occurs. Adolph and Avolio (2000) examined whether toddlers could adapt to changes in their body dimensions and variations in the terrain by loading them with lead weights and observing how they navigated safe and risky slopes. Toddlers could adapt to experimental manipulation of their body dimensions since they were more likely to walk down the same degree of slope while wearing the feather weights than the lead weights. However, the adjustment is neither immediate nor perfect. On slopes slightly steeper than infants' walking boundaries, infants made more errors loaded with lead packs than with feather packs. Those errors may have resulted from differences in infants' exploratory activity, since toddlers explored less while loaded with lead weights. The process of adaptation to new action capabilities is also evident in the early stages of learning. Adolph (2000) tested reaching and avoidance responses of ninemonth-old infants, at a precipice of safe and risky gaps, comparing an experienced sitting posture and a less familiar crawling posture. Babies avoided reaching over risky gaps while sitting, but attempted to reach and fell into those gaps while crawling. Experience with an earlier-developing skill did not transfer directly to a later-developing one, indicating that infants must learn, posture by posture, how to discover relevant information and use it for prospective control of action (Adolph, 2000). It becomes clear that risk behavior must be ecologically defined, as it relates to individuals' characteristics that change in time as to specific environmental demands.

Indeed, risk emerges from a relationship – it is not a property of the individual and it is not intrinsic to the environment. According to J. J. Gibson (1979) the individual guides his/her activity by perceiving affordances, so he/she must be capable of perceiving the relationship between environmental properties and the properties of his/her own action system.

**2.6. Risk as a particular kind of affordance**

Gibson used the term affordance to describe the possibilities for action provided for the actor by the environment. To perceive an affordance, is to perceive how one can act when confronted with a particular set of environmental conditions. Affordances need not to be mediated via cognitive representations, but rather they can be directly perceived (J. J. Gibson, 1979). Perception of affordances may be direct, but knowing what specifies an affordance can be a long-term process. In some cases the perception of an affordances is innate (e.g., a child has a defensive response to a "looming" object), but in other cases it is learned. This process of learning does not imply a "representation" of anything. Children will not detect risk by means of labels or instructions. Instead, they will perceive risky objects or surfaces because they learn to differentiate environmental information, and to relate it to information about their own effectiveness in that environment. The process of discovering what information specifies an affordance was termed perceptual learning (E. J. Gibson & Pick, 2000). To perceive an affordance the child should be attuned to some environmental properties in order to guide his/her behavior. The classic Gibson and Walk (1960) study of the "visual cliff" has demonstrated that children reliably use the visual information of a cliff, even though their hands felt the supporting glass and despite of their mother's encouragement. This study is a strong argument not only to show that visual perception of depth is extremely developed by the age of 6 months, but also to demonstrate that visual constraints can clearly shape behavior. Risk is not a characteristic of the environment, as most injury prevention policies have emphasized. For example, the efficacy of standards for safety barriers to prevent access to swimming pools or falls from balconies, depends largely on the child's characteristics

(Cordovil, Barreiros, Vieira, & Neto, 2009). An environment is risky with respect to the specific action capabilities of a given actor. The affordances are specified within a unique set of references for each individual that takes into account both his characteristics and the properties of the object. Therefore, what constitutes a certain affordance for one person might not constitute the same affordance for another. A chair with a comfortable height for an adult might not afford sitting without an adult's help to a child. An adequate perspective for safety in childhood must account for the individuality of what constitutes an affordance for a certain child. What individuals perceive in the environment is not a simple metric description in units of distance, volume, light, or temperature, but their possibilities for action, what they perceive is what is possible and what is not possible (Fajen, Riley, & Turvey, 2009; Stoffregen, 2003). The individual picks-up relatively permanent aspects of the environment, or invariant properties, which specify his/her action determining, for instance, if an object is close enough to reach and grasp, if a slope isn't too steep to walk, or if an obstacle isn't too high to cross.

There is supporting evidence that some actions are "body-scaled", in a morphological and functional basis, and perception works in intrinsic units related to the individual action capabilities and biomechanical constraints and not by extrinsic units or absolute measures. For instance, grasping is a body-scale action. Van der Kamp, Savelsbergh, and Davis (1998) and Barreiros and Silva (1995) verified that a shift from one-handed to two-handed grasping occurs at the same body-scale ratio between object size and finger span for children between 2 and 9 years of age. The changes of children's grip configuration were studied by Cesari and Newel (2000), who verified that a dimensional ratio between length and mass of an object and length and mass of the child's hand could predict the transitions of the grip configuration used in prehension. Points of transition between grip configurations in children were the same that had been previously identified in adults (Cesari & Newell, 1999), indicating that the invariant body-scaled relation that specified the adult grip transitions also held for the 6- to 12-year-old children.

Whereas some affordances, such as grasping, are clearly constrained by children's body dimensions, others are constrained by their action capabilities. In catching a flying ball, for example, the catchableness of a fly ball depends less on children's body dimensions, and more on their running (and perhaps even jumping) capabilities. Such affordances are action-scaled rather than body-scaled (Oudejans, Michaels, Bakker, & Dolne, 1996). In some situations, such as street crossing, the correct perception of action-scaled affordances might be fundamental in terms of safety. Children and adults must be able to perceive which temporal gaps between traffic afford safe crossing according to their own characteristics, such as time to initiate the action of crossing and walking speed, and they must continuously adapt locomotion behavior to changes in the traffic situation (te Velde, van der Kamp, Barela, & Savelsbergh, 2005).

The perception of action-scaled affordances is important, not only in making decisions about different modes of action (i.e., cross the street now or wait for a greater temporal gap between traffic), but also in the ongoing guidance of action, as proposed by the new affordance-based models of perceptually guided action (Fajen, 2005). These models challenge the classical 'double process' view according to which the selection of an action mode precedes the control of the action, proposing that affordances are perceived not only before the action, in order to support the appropriate action mode selection, but also throughout the execution of the action to monitor its control.

One issue concerning action-scaled affordances that warrants future research is the accuracy and precision with which action-scaled affordances can be perceived. For the perception of action-scaled affordances actors must use static (e.g., size or distance) and kinematic (e.g., velocity or acceleration) information about objects to scale their actions appropriately. Some studies have examined children's behaviors in collision avoidance tasks indicating that children have more unsafe behaviors than adults in this kind of tasks (e.g., Plumert, Kearney, & Cremer, 2004; te Velde, van der Kamp, & Savelsbergh, 2008). Plumert et al. (2004) verified that children (10 and 12 year-olds) and adults chose the same size temporal gaps to bicycle across a virtual traffic environment. Gap sizes were temporally invariant, meaning that participants integrated information about speed and distance while judging gap sizes, and choose larger distances between cars when the cars were travelling faster. However, children ended up with less time to spare between themselves and the approaching car by the time they reached the end of the roadway. Te Velde et al (2008), using a toy scenario, asked children (5 to 7 year-olds and 20 to 12 year-olds) and adults to push a doll across a small-scale road avoiding collisions with toy vehicles. The youngest children (5 to 7 year-olds) attempted to cross less often but collided more frequently than the adults. The results of these studies indicate that perceptions and actions in collision avoidance situations are not as attuned in youngest children as they are in eldest age groups. Besides the developmental changes, one can imagine that the perception of action-scaled affordances is particularly challenging, since it is influenced by temporary constraints, such as fatigue. Children often try to gain experience by pushing the limits of their capabilities, and they probably do that while learning to perceive their action-scaled affordances.

Whereas we consider body-scale or action-scale affordances, the matching between individual's characteristics and environment offers is a very good candidate to define what risk or safe behaviors may be. Importantly, affordances may arise and dissolve over time. In some situations the actions of the child might create new affordances even though the surfaces and objects in the environment remain the same. That is the case of a child that approaches a swimming pool, getting close enough to jump in the water, a behavior that would not be possible from a more distant location. In other cases, affordances are created by changes that occur in the child's environment while the child remains static. That is what happens when a child stands in the sidewalk trying to judge a big enough gap to cross the street. Finally, both the child and the environment might change creating new affordances, as it happens when a child cycles through a crowded city. Action possibilities can evolve and devolve rapidly, and also over longer time scales. As children grow, those action potentials change, sometimes very smoothly, and sometimes very rapidly. Therefore, what is risk behavior at a certain moment may not be at another moment. An ecological definition of risk should consider it as a particular kind of affordance because it is a relational and dynamic concept: risk is a relational concept since it emerges from the individual/environment interaction, being neither a property of the individual nor intrinsic to the environment; and it is a dynamic concept since it evolves over time as the interaction between the individual and the environment changes.

### 2.7. Experience and the perception of risk affordances

Research with children indicates that the perception of affordances occurs relatively early in their development (see Ulrich, Thelen, & Niles, 1990, for a review). However, the perceptual system is not mature at birth – it needs time for biological maturation, and experience to refine perceptual competence. The combined effects of maturation and experience promote a greater distinction of the environment features. Many studies strongly suggest that experience is of an extreme importance in perceiving affordances (Adolph, Eppler, & Gibson, 1993; Klevberg & Anderson, 2002; Ulrich et al., 1990; Zwart, Ledebt, Fong, de Vries, & Savelsbergh, 2005).

Eleanor Gibson (1969) convincingly argued that with experience, people learn the strategy that is most economical for the task at hand and thereby focus on the minimal number of invariants that will successfully discriminate among those events of interest. Differences between children at different skill levels may reflect (at least in part) differences in perceptual attunement. Perceptual attunement refers to changes over a period of practice in the informational variables upon which actors rely (Fajen et al., 2009; Jacobs & Michaels, 2006). To the extent that novices rely on non-specifying variables to perceive action-scaled affordances, their ability to reliably distinguish between possible and impossible actions across a range of conditions will be degraded (Fajen & Devaney, 2006).

There is a growing body of research concerning the process of attunement in adult learning (e.g., Jacobs & Michaels, 2006; Wagman, Shockley, Riley, & Turvey, 2001) but studies of attunement during development are more scarce (van Hof, van der Kamp, & Savelsbergh, 2006, 2008). Skilled perception of risk affordances evolves with practice, and cumulative experience under different environmental constraints seems to be a good way of learning. Some studies (Schwebel, 2004; Schwebel, Lucas, & Pearson, 2009) have tried to diminish children's overestimation tendency in risk situations either by imposing a period of forced latency before children's decisions in risk situations or by introducing visually salient stimuli in risk scenarios. However, despite the longer decision latencies in both situations, children's accuracy did not improve in any of the scenarios. These results seem to indicate that experience in acting in a given task might be necessary for children to be attuned to the relevant information in that task. The role of experience in the perception of relevant information about the environment is also illustrated by some studies with the visual cliff task (Campos, Langer, & Krowitz, 1970; Schwartz, Campos, & Baisel, 1973). These studies suggest that the perception that the visual cliff did not afford crawling emerged at a developmentally appropriate stage. When 5-months-old infants were lowered next to the cliff they did not perceive the situation as unsafe and their hear rate decelerated. Conversely, when 9-month-old infants near the cliff their heart rate accelerated, suggesting that self produced locomotor experience, which is present in 9-months-old but not in 5-months-old infants, might contribute to the avoidance of heights. In fact, the need to perceive a drop-off as a negative affordance for locomotion seems irrelevant for infants that depend on others to move around. During development infants and toddlers learn how to move in different environments, as their own body's proportions, strength and capacity for balance are changing. Initially, they are notoriously prone to falls from more or less high places, but with maturation and experience, they soon find out how to avoid most accidents on their own (E. J. Gibson & Pick, 2000). Infants learn to avoid falling-off places not necessarily by experiencing falling a number of times, but probably by learning how to identify which surfaces afford support. The detection of affordances provided and tuned by experience in early locomotor stages will be of great help in later developing skills.

During development, children learn to perceive affordances in a world designed mostly by and for adults. However, more experience does not mean that children's actions become more predictable, since children frequently act in many creative ways. For instance, Ulrich, Thelen and Niles (1990) studied infants (M=13.3 ± 2.24 months) and toddlers (M=20.5 ± 2.30 months) climbing three sets of stairs with different riser heights (3 in, 6 in and 12 in). Young infants perceived the small and medium steps as climbable and their choices were unrelated to their body size but dependent on their walking or stair-climbing experience. In the younger group, 9 children (41%) chose to climb straight to a toy that was on the top of the stairs, but of the 25 older children, only 4 (16%) did so. Older children's choices were unrelated to their body size and to their walking or stair-climbing experience. Apparently older children perceived that stairs afforded a variety of actions and they played, exhibiting a number of different action capabilities as children usually do.

Inefficient or dangerous behaviors usually occur when people, especially children, are close to their action boundaries. When a wall is too high it inhibits jumping; when it is low enough, jumping is promoted; but in the boundary zone there is an increased uncertainty that might lead to a risk behavior. This boundary area is usually the most unsafe one, and the precise delimitation of affordances requires specific experience on specific environmental constraints. At this point a new paradox emerges: children may experience dangerous behavior because they have no experience but learning by experience seems to be dangerous.

**2.8. Reanalyzing "risk environments" and "risk children"**

It is known that in some environments a non-accurate perception of affordances might have more serious consequences than in others, and that some subjects might have greater difficulties to be attuned to the relevant environmental invariants than others. However, by defining risk as a particular type of affordance we consider that there are not really "risk environments" and "risk children", but risk interactions between children and environments that occur when the child is not attuned to some environmental properties in order to guide her behavior. An unfenced swimming pool, for example, constitutes a situation of a greater risk to a toddler than to an adolescent that knows how to swim and that is attuned to the information that correlates with risky behaviors close to the water. However, if that teenager's capability to be attuned to relevant information is altered, for instance due to alcohol consumption, being near an unfenced swimming pool might constitute a risk affordance. Drowning can occur in a variety of different locations, such as bathtubs, pools, ponds, streams, lakes, rivers, and the sea (Peden et al., 2008; Vincenten, 2004). The place of drowning is related to age. For instance, in the United States, infants most commonly drown in baths and buckets, and 1 to 4 year-olds most commonly drown in swimming-pools (Brenner, Trumble, Smith, Kessler, & Overpeck, 2001; Peden, 2008). Coss, Ruff and Simms (2003) presented two experiments that demonstrated a tendency of infants and toddlers to mouth glossy surfaces. The authors provide an interesting explanation for this behavior, suggesting that infants and toddlers have the precocious ability to perceive the optical information for water. This study indicates that some affordances are particularly important at certain developmental stages and that significant affordances at an earlier stage might not be the same in a later stage. In addition, it shows that to be attuned to the information to detect water, even before this information is useful later in development, might increase infants and toddlers probability for drowning.

In some situations, to be attuned to relevant environmental cues might be particularly difficult. For instance, objects and places with high temperatures might lead to burns and scalds. However, temperature, a key variable in this kind of accidents, is not visually nor acoustically available – it is a particular, and momentary, energetic state of objects. To get information about objects' temperature one must touch, or alternatively, learn about their effects on the body when touched. A pot over a stove has a higher chance of being hot and a blue-and-yellow light under the pot increases that chance. None of these conditions directly affords a non-grasping or a non-touching action unless the individual has the possibility to actively touch the pot. The same problem exists in electric hazards, as any individual can experience.

Although boys routinely experience more injuries than girls (Crawley, 1996; Morrongiello, Ondejko, & Littlejohn, 2004), children, regardless of gender, rate girls as having a greater probability of injury than boys for the same activity (Morrongiello, Midgett, & Stanton, 2000). However, the differences in risk-taking behaviors between boys and girls, that are usually considered to result from a purely individual constraint (i.e., gender), result, in fact from socialization practices. Morrongielo and Dawber (1998) examined the socialization practices of mothers and fathers of children between 2 and 4 years-old during a free-play episode and while parents taught the child a playground behavior with some probable dangers (i.e., going down a firehouse-type pole). Results indicated that parents socialize boys and girls differently, since they demanded more independence in their sons, encouraging them and providing fewer explanations, and more caution in their daughters physically assisting them. This differential treatment existed although there were no gender differences in children's playground skills or their abilities to complete the task independently. Morrongiello and Dawber (2000) achieved similar results when studying mother's responses to their children's risk-taking behavior with mothers of older children (i.e., between 6 and 8-years-old). Results indicated that mothers of daughters were more likely to judge behaviors as involving some probability of injury, and they intervened more frequently and quickly than mothers of sons. Mothers perceive that risk-taking behavior in boys is more acceptable than it is for girls. The different socialization practices adopted by parents when responding to their children's risk-taking behavior promote differences in the kind of environmental information their children became attuned to.

**2.9. Constrain risk affordances**

A socially relevant aspect of understanding risk affordances for children is that adults create the ecologies where children act. Therefore, we face the interesting problem of understanding how adults perceive affordances for children.

There are some indications that adults can be quite accurate in perceiving the affordances of other adults (e.g., Fischer, 2003; Mark, 2007; Ramenzoni, Riley, Shockley, & Davis, 2008; Rochat, 1995; Stoffregen, Gorday, Sheng, & Flynn, 1999; Stoffregen, Yang-Yi, & Gorday, 1995), but only a few studies (Cordovil & Barreiros, 2009, in press) have approached the evaluation of a child's action limits by an adult, which is probably one of the most common and relevant situation of affordances' detection. Adults have a tremendous responsibility in what concerns the arrangement of children's physical environment, and for that reason wrong judgments about the action limits of a child might lead to risky situations.

Parental supervision has been considered an essential determinant of children's safety. Lapses in appropriate supervision have been identified as a factor across a range of childhood injuries (Morrongiello, 2005; Saluja et al., 2004). Peterson, Ewigman and Kivlahan (1993) stated that there is no substitute in most risky situations for developmentally appropriate parental supervision of young children. However, to define adequate supervision we must consider a variety of constraints, such as the age of the child, the hazards present in the environment and the type of injury to which the child is exposed. For example, an adequate supervision of a 5-month-old baby in a swimming pool implies touch and continuous attention, while intermittent attention from a distant location might be adequate supervision for 5-year-old playing in the bedroom.

Caregiver decisions about injury prevention strategies might be environmental oriented, such as hazard reduction/elimination, or individual oriented, such as teaching safety rules, injury prevention behaviors (Saluja et al., 2004). These strategies depend on their risk perception that is also influenced by the social environment in which the caregiver and child are living. Consequently, the caregiver behaviors are influenced by a variety of interacting constraints. Miller, Shim, and Holden (1998) showed that maternal behaviors toward 3-year-old children varied significantly as a function of the environment, and the demands of the mothers. It seems that in situations where the adult considers that the child is in a risky situation, there is a tendency to inhibit the exploratory process using, for instance, more verbal prohibitive behaviors.

Prevention of childhood injuries has led to a debate concerning the relative merit of focusing on modifying the environment versus a person's behavior in order to reduce the probability of injury. Researchers have tried to devise ways to decrease the necessity for supervision by pursuing different kinds of interventions to reduce environmental hazards (e.g., stair safety barriers, swimming pool fences, safety plugs or bicycle helmets). However, so long as the children depend on the caregiver to shut the stair safety barrier or the swimming pool fence, to put the safety plug on the electrical outlet, or to remind them to wear the bicycle helmet, caregiver behavior will remain of fundamental importance. Besides that, environmental modifications might lead sometimes to ironic effects (i.e., increased risk taking behavior in adaptation to environmental modifications intended to reduce risk taking behaviors). This behavior has been demonstrated in children (e.g., Morrongiello, Walpole, & Lasenby, 2007) and in parents, who allow children to engage in greater risk taking behavior when wearing safety gear or when environmental modifications reduce risk perception (Morrongiello & Major, 2002). As Morrongiello (2005) pointed out not all environments can be modified to reduce the possibility of injury, and not all behaviors are easily amenable to modification. Hence, both kinds of strategies should be viewed as complementary and equally important to the prevention of childhood injuries.

As we have mentioned before, children are not merely in a natural environment full of affordances. In fact, children move in a modified environment, selectively structured. For example, a playground is a concentration of affordances that aims to pre-adapt children to the development of cycles of activities typical of a culture. Interestingly, the structured environment changes in time, with changes in child development. These modified environments are characterized by the presence of caregivers, by the existence of objects, places and events selected for children (toys, equipment and surfaces) or selected to be kept away from children (guns), and by the promotion of play. Reed (1996) argued that these are the conditions for the field of promoted action, which is characterized precisely by the presence of affordances for children as perceived by adults; the exclusion of negative affordances for children as perceived by other people, and the inclusion of scaffolding for actions in children in different timings.

Importantly the activity of children starts before they have the autonomy to realize affordances to which the task is directed. Children do things before they know how to do them (Reed, 1996). This may be the indicator for caregivers to start helping them to develop a certain skill. We can conclude from this that children act towards objects or surfaces, while learning how to act with those objects, or on those surfaces. That is why children place themselves in a position of encouraging adults to help them in promoting their action.

Caregivers in all cultures promote the acquisition of competence in everyday skills. This is done by organizing the places of the environment and the daily routines of children in ways that promote a gradual process of awareness and accomplishment. Despite many real crosscultural differences, there are probably some important similarities in cognitive development: the understanding of causal relationships and sequential dependencies, the learning of task-specific relationships of affordances, and of the specific interrelationships among tasks that constitute a daily routine. According to Reed (1996) there appears to be a universal tendency for children to engage in actions with "unfilled" meaning. This tends to act as a trigger for intense and task-specific scaffolding of the relevant tasks by caregivers.

The role of caregivers in constraining risky affordances for children, by supervising children's behaviors and by structuring the environment, is specific to each child developmental stage. Infants are continuously exploring the world. As van Hof pointed out "Exploration is an ongoing coupling between actions and perception by which infants learn to perceive what actions are appropriate in a particular situation" (van Hof, 2005, p.9). As the child's action capabilities develop the amount of opportunities for exploration increases and new affordances are created. A reduction of experiences acts in an inverse direction. Probably, younger infants will not perceive affordances as accurately as older children, and they have more chances to choose risky behaviors. In the categories of accidents that we've previously described, a higher prevalence of registered events was found in those developmental stages.

As the intrinsic dynamics of the child develops new affordances become potentially detected. This is a reciprocal interweaving process that broadens the limits of action. It is also a specific and individual process. As children grow and fundamental patterns begin to stabilize the detection of affordances becomes more predictable. In periods of fast body modifications some motor patterns are also under high rates of change. The combination of these two factors (body dimensions and motor behavior) influences the way children perceive and act in the world. We know that the detection of affordances is an experience based process, but nobody knows exactly how it happens. For instance, measures of body dimensions have proven unsuccessful at identifying affordance boundaries with very young children with limited motor experience (Adolph et al., 1993). At a developmental level of analysis, variables such as height or body mass, alone, are not good predictors of behavior. A main reason for this trend in literature is that scaling the world seems a plausible solution for adjusting actions when between-subject variability is a consequence of variability in mass and geometry. This is not the case in very young children: they can make good use of a diversity of solutions and that is the primary source of behavioral variation. Information that specifies affordances should be specific to both structural and dynamic variables of children and environment. Developmental differences in dynamic action capabilities seem to be a promising explanation for perceiving affordances.

Another interesting aspect is that perception of affordances boundaries improves with practice. In experiments with adults it was demonstrated that subjects that were allowed to move around in order to explore their artificially altered dimensions showed increasingly less movement variability and increased accuracy in the determination of affordance boundaries (Mark et al., 1990). Unfortunately, experimental modification of body dimensions in children has not been studied, but there is no reason to expect different results.

In sum, during the process of discovering what the world has to offer the infant sometimes engages in risky situations. In terms of child safety it would be important to determine not only how the child perceives risky affordances, but also how the adult perceives risk for that child, since in the early years the environments the child moves in are controlled and managed by adults. A better understanding of child's interaction with different environments and of the accuracy of adult's risk perception, will help parents or caregivers to know what constraints should be dealt in different situations, so that the children's active exploration of the world can go on in a safe environment.

We would like to emphasize that a safe environment is not the same as a risk free situation. Not only because a risk free environment is difficult to achieve, but also because we believe there are positive developmental outcomes associated with risk-taking behavior. The overwhelming emphasis on injury prevention in the current literature has neglected the positive aspects of risk-taking. However, exploration, challenges and the experience of risk affordances have an important role on children's development since they provide valuable opportunities for learning, problem-solving and developing social competence. As Greenfield said: “In today's society there appears to be an aversion to risk; yet, without risk-taking we do not reach our potential” (Greenfield, 2004, p.1). As a matter of fact, parental and society apprehension concerning child's safety is resulting in an increasingly overprotecting style of parenting and aversion to risky situations, where possible dangers are exaggerated and safety and caution are strongly promoted. This attitude might result in the avoidance of many worthwhile risky affordances that contribute to child's development. On the other hand, the removal of all potential hazards may inadvertently lead to inappropriate risk-taking, since children can seek challenging and stimulating experiences to overcome boredom and lack of stimulation (Little, 2006).

As Eleanor Gibson (E. J. Gibson, 2003) remarked, following Stevenson's words, “The world is so full of a number of things” and children are so curious about them all that it is the duty of caregivers to help them in the discovery process to become attuned to the affordances that are worthwhile to select.

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# 3. Egocentric or allocentric frameworks for the evaluation of other people's reachability


### 3.1. Abstract

The adoption of egocentric and allocentric frameworks in the perception of other people's reachability was investigated. In study 1, 24 adults (12 experienced and 12 inexperienced dealing with children) judged vertical reachability for themselves and for two children. In study 2, 37 parents judged vertical reachability for themselves and their children. Absolute errors (|estimate-actual reachability|), absolute percent errors (|1-estimation/actual reachability|x100), and error tendency (underestimations, right judgments, or overestimations) were calculated. Adults were quite accurate in perceiving their own reachability (absolute percent errors ranging from 2.20% in study 1 to 3.12% in study 2) and clearly less precise when estimating children's reachability. Results indicated a tendency for adults to overestimate reachability of the younger child, and a tendency for parents to overestimate their children's reachability. No correlation between estimation errors for the self and for the children in any of the studies was observed. Results support the existence of an allocentric and not an egocentric framework when evaluating other people's affordances.


Keywords: children's affordances; perceptual attunement; reaching.

### 3.2. Introduction

The information that specifies affordances is public (Gibson, 1979), which means that it is available not only to the perceiver but also to other people. Some studies (Mark, 2007; Rochat, 1995; Stoffregen, Gorday, Sheng, & Flynn, 1999) indicated that humans can make use of that information to perceive other people's affordances, suggesting that observers are capable of taking the perspective of the other and switch from a mode centred on the self (egocentrism), when perceiving affordances for themselves, to a mode centred on the other (allocentrism). The ability to shift from an allocentric to an egocentric framework has been reported in children (Rochat, 1995), which supports Gibson's idea that "The evidence about the earliest visual experiences of infants does not suggest that they are confined to surfaces seen-now-from-here… I therefore suspect that the supposed egocentricity of the young child is a myth" (Gibson, 1979, p. 201). The assertion "I can put myself in your position" (Gibson, 1979, p.200) is not a mere figure of speech, meaning that an observer can perceive the information available to another person, without having to occupy his/her point of observation. The perception of other people's maximum capabilities, specifically of children's action boundaries, such as the highest place a child can reach, is of paramount importance in terms of child safety. It is important for parents and caregivers to correctly judge whether an object is within vertical reach of a child. The role of parents and educators in the management of environmental conditions has been widely reported in the literature about child safety and prevention of childhood injuries (Morrongiello, 2005).

Studies on the perception of self-reachability indicate that estimations of this action capability are quite accurate, but present a systematic overestimation bias (Carello, Grosofsky, Reichel, Solomon, & Turvey, 1989; Fischer, 2005; Gabbard, Ammar, & Lee, 2006; Gabbard, Ammar, & Rodrigues, 2005; Pepping & Li, 2000; Rochat & Wraga, 1997). Some studies (Cordovil & Barreiros, 2008; Fischer, 2003; Ramenzoni, Riley, Shockley, & Davis, 2008b; Rochat, 1995) also indicate that individual's can be reasonably accurate in the perception of other people's reachability. However, the overestimation bias is not as consistent as in the estimation of self-reachability. Some studies have detected an underestimation bias for some selected sample groups (Cordovil & Barreiros, 2008; Ramenzoni et al., 2008b; Rochat, 1995).

In a recent study Chang, Wade and Stoffregen (2009) addressed the interesting issue of perceiving affordances for an environment-adult-child system. Adults were required to determine the minimum passable aperture width for the dyad when the adult and the child walked side by side. Results indicated that adults perceive affordances for aperture passage for the environment-adult-child system on the basis of the body-scaled information of each adult-child dyad, perceiving their own plus the child's characteristics. However, some adults underestimated while other adults overestimated the action capabilities of the dyad, which does not support the idea of a systematic overestimation of action capabilities.

The perception of other people's affordances might be influenced by several factors, such as the characteristics of the model, the position of the observer relative to the model and to the context, the observer's characteristics (e.g., level of experience), or the morphological and functional differences between the observer and the model (Fischer, 2003; Ramenzoni et al., 2008b; Rochat, 1995). There are indications that perceiving affordances for another person may not be independent of the observer's capacity to act in the environment at a given moment, suggesting an influence of the egocentric framework in allocentric estimations (Ramenzoni, Riley, Shockley, & Davis, 2008a). A strong argument for this perspective was provided by Ramenzoni et al. (2008a) in a study about the effects of sudden changes in body weight characteristics in the perception of the affordances for the self and for the others. The results showed that the participants adjusted the estimations for their own reachability, but they did so also for the other persons who were not wearing additional weights.

The assumption that we apprehend the actions afforded to another person with regard to our own capacity to produce action suggests a relationship between egocentric and allocentric frameworks in the perception of other people's affordances. The relationship between the two frames of reference seems influenced by perceptual experience and tuned in relatively short learning periods (Ramenzoni et al., 2008a).

This investigation will attempt to clarify the contrast of egocentric and allocentric frameworks in adults' perception of children's vertical reachability, the influence of adult's experience dealing with children (study 1), and the effects of child specific knowledge by parents (study 2).

## 3.3. Study 1

### *3.3.1. Method*

#### *3.3.1.1. Participants.*

Twenty-four adults, from 20 to 64 years old (M=37.76, SD=11.15), with maximum reachability ranging from 197.80 cm to 250.20 cm (M=219.75, SD=13.90), and with normal or corrected-to-normal vision. The adults were divided in two groups according to their level of knowledge about the children: (i) Inexperienced – 12 adults (5 males and 7 females), with ages between 20 and 54 years (M=31.2; SD=9.5), with no children or younger brothers in the family, and with no experience or daily contact with children; (ii) Professional caregivers – 12 female adults, with ages between 31 and 64 years (M=44.3; SD=8.7), with prolonged experience (more than two years) dealing with children.

#### *3.3.1.2. Models.*

Two boys with 1.72 and 3.60 years of age, height of 83.2 cm and 99.5 cm, and with maximum reachabilities of 100.2 cm and 127.4 cm.

#### *3.3.1.3. Procedures.*

A shelf that could be raised or lowered (1.6cm intervals, from 65cm to 228.2cm) was used to estimate children's reachability. Identification numbers between 1 and 103 were marked on the side of the shelf with no direct correspondence to the real height in centimetres to avoid the association to a well-known metric reference. A toy (3.5cm high, 3cm wide and 6.5cm long) was placed on the shelf.

The child entered the room and stood close to the shelf facing the observer, with the arms at the sides. The order of presentation of the children was randomized. Observers stood 2m away from the shelf and were instructed to look at the child and register on their record form the maximum height of which they thought that he would be able to take the toy off the shelf. To register that measure (i.e., maximum vertical reachability), they should look at the marked side of the shelf and write down the highest number they thought the child would reach. The observers were told that the child was allowed to stand on tip-toes and touch the shelf, but was not allowed to climb or jump to complete the task. After that the shelf was readjusted for the adults (from 95cm to 258.2cm) and each observer was asked to estimate his/her own maximum vertical reachability in the same conditions and from the same place previously occupied by the child. Finally, the maximum vertical reachability of each child and of the observers was determined. The actor (child or adult) extended his/her arm and the shelf was adjusted starting from that position, being raised 1.6 cm after each successful attempt and lowered 1.6 cm after each failure. The maximum vertical reachability was the highest value in centimetres, at which the actor was able to successfully take the toy off the shelf, in the previously described manner.

Previously to the data collection, the school board in question was fully informed of the purposes of the study. Approval from the Ethics Committee of Faculty of Human Kinetics (Technical University of Lisbon, Portugal), and informed consent from the parents of the children and the observers that participated in the study, were obtained.

*3.3.1.4. Data collection and analysis.*

The following variables were considered: estimation error in centimetres (i.e., difference between the estimated and the real maximum vertical reachability) and intrinsic errors (i.e., the ratio between the estimation and the real maximum vertical reachability) (cf., Ramenzoni et al., 2008b). The intrinsic error is expressed in “intrinsic” units of the model’s own capabilities, and it represents: (i) perfectly accurate estimations (ratios equal 1.0) when perceptual judgement equals the actual reaching height; (ii) underestimations for ratios lower than 1.0, and (iii) overestimations for ratios greater than 1.0. Absolute errors (i.e., |estimation error|) and absolute percent errors (i.e., |1-intrinsic error|x100) were calculated. Error tendency (i.e., underestimation, accurate estimation, or overestimation) was also determined for each observation.

For the statistical analysis of perceiver's accuracy, Friedman's test was used to compare absolute error and absolute percent error for the children and for the observers. As post hoc, the Wilcoxon test, with Bonferroni correction, was employed. Error tendency was analyzed through frequency distributions. To analyze the correlation between errors for self-reachability and for children's reachability, the Spearman correlation was employed.

### *3.3.2. Results*

Accuracy of estimations was analyzed through the values of absolute error (AE), which indicate the deviation in centimetres from accurate estimations, and through the values of the absolute percent errors (APE), which indicate the deviation percentage from accurate estimations (see Table 3.1).

Table 3.1. Mean (M) and standard-deviation (SD) of absolute error (AE) and absolute percent error (APE) in the estimations of reachability for the two children and for the observers. Values for the whole sample and for the two sample groups (inexperienced and teachers).

| Error | Group | Child 1 | | Child 2 | | Observer | |
|---|---|---|---|---|---|---|---|
| | | M | SD | M | SD | M | SD |
| AE (cm) | Whole sample | 5.00 | 4.51 | 6.93 | 5.48 | 4.87 | 3.79 |
| | Inexperienced | 5.20 | 5.42 | 8.67 | 6.52 | 5.87 | 4.79 |
| | Teachers | 4.80 | 3.61 | 5.20 | 3.68 | 3.87 | 2.21 |
| APE (%) | Whole sample | 4.99 | 4.50 | 5.44 | 4.30 | 2.20 | 1.74 |
| | Inexperienced | 5.19 | 5.41 | 6.80 | 5.12 | 2.57 | 2.22 |
| | Teachers | 4.79 | 3.60 | 4.08 | 2.89 | 1.82 | 1.05 |

Mean errors in the perception of reachability ranged from 4.87 cm, or 2.20%, for self-estimations and 6.93 cm, or 5.44%, for the taller child's estimations. There were no significant differences in the absolute error for the children and for the observers in the whole sample ($\chi^2(2)=1.640$, $p=0.440$), in the inexperienced group ($\chi^2(2)=4.578$, $p=0.101$), or in the teachers' group ($\chi^2(2)=0.409$, $p=0.815$). However, Friedman's test revealed significant differences in APE for the whole sample ($\chi^2(2)=7.000$, $p=0.030$) and for the inexperienced group ($\chi^2(2)=6.176$, $p=0.046$). Wilcoxon test, with Bonferroni correction, was used as post hoc, and revealed that, when considering the whole sample, APE in child 2 estimations was significantly greater than APE in self-estimations ($Z=-2.857$, $p=0.004$), and there was a marginal significant tendency for APE in child 1 to be greater than APE in self-estimations (Z=-2.200, p=0.028). In the inexperienced group, post hoc tests only indicate a marginal significant tendency for APE in child 2 to be greater than APE in self-estimations (Z=-2.197, p=0.028).

Values of AE and APE were always smaller in the teachers group than in the inexperienced group, but those differences were not significant.

Error tendency was analyzed based on the frequency of underestimations, accurate estimations and overestimations (Table 3.2).

Table 3.2. Frequency of underestimations (% Under.), accurate estimations (% Ac.) and overestimations (% Over.), for both children and for the observers, in the whole sample and for the two sample groups (inexperienced and teachers).

| Group | Child 1 | | | Child 2 | | | Observer | | |
|---|---|---|---|---|---|---|---|---|---|
| | % Under. | % Ac. | % Over. | % Under. | % Ac. | % Over. | % Under. | % Ac. | % Over. |
| Whole sample | 16.67 | 16.67 | 66.67 | 58.33 | 4.17 | 37.50 | 37.50 | 8.33 | 54.17 |
| Inexperienced | 25.00 | 16.67 | 58.33 | 75.00 | 0 | 25.00 | 50.00 | 8.33 | 41.67 |
| Teachers | 8.33 | 16.67 | 75.00 | 41.67 | 8.33 | 50.00 | 25.00 | 8.33 | 66.67 |

There was a tendency to overestimate reachability of child 1 (66.67%) and to underestimate reachability of child 2 (58.33%), which was due to a strong tendency of the inexperienced group to underestimate the older child (75.00% of underestimations). Inexperienced adults had a slight tendency to underestimate self-reachability (50.00% of underestimations), while teachers revealed a tendency for overestimation regarding self-reachability (66.7% of overestimations). In the whole sample there was an overestimation tendency for self affordances (54.70% of overestimations and 37.50% of underestimations).

We found no significant correlations between errors for self-reachability and for children's reachability. The non-existence of correlation is systematic and was verified in the whole sample and for the two sample groups (inexperienced and teachers), for estimation errors, intrinsic errors, absolute errors and absolute percent errors.

In the whole sample we verified a significant correlation between estimation errors for child 1 and child 2 ($r_s$=0.531, p=0.008), and between intrinsic errors for child 1 and child 2 ($r_s$=0.531, p=0.008). However, when considering the two sample groups separately, that correlation was not observed.

*3.3.3. Discussion*

The magnitude of AE and APE of the present study indicate that adults are capable of predicting their own affordances quite accurately. The estimation of children's affordances also seemed to be adjusted to children's real action capabilities, but with less accuracy (i.e., greater APE values), mainly in child 2 estimations. The evaluation of child 2 also had contradictory results in what concerns error tendency of the two sample groups, since most inexperienced adults (75.00%) underestimated this child's capabilities, while there was a slight overestimation tendency in the teachers group (50.00%). The underestimation tendency of children's reachability by inexperienced adults had already been verified in previous studies (Cordovil & Barreiros, 2008) and it is a concerning child safety issue since it might result in relaxed supervision behaviors. On the other hand, there was an overestimation tendency of child 1 reachability in both sample groups (66.67% overestimations in the whole sample). The tendency to overestimate the youngest child's reachability might indicate a difficulty of adults to consider children's body proportions (i.e., bigger heads and smaller arms), considering them as small adults. This hypothesis needs further research.

The teachers group had lower values of AE and APE than the inexperienced group in the evaluations of both children's affordances and of self affordances, suggesting that adults who had daily professional experience with different children might have undergone a perceptual learning process that resulted in more accurate judgments than inexperienced adults.

The absence of correlation between errors in self-reachability and in children's reachability indicates that there is a shift to an allocentric referential in the estimation of other people's affordances. The significant positive correlation between estimation errors for child 1 and child 2 ($r_s$=0.531, p=0.008) was expected, since the perceptual processes inherent to the estimation of other people's reachability must be identical, particularly if the morphological differences between the models are not too discrepant, as it is the case of the difference between the two children.

**3.4. Study 2**

In study 2, we investigated the influence of a great knowledge of the model in the participation of the egocentric and the allocentric frameworks, in the perception of children's vertical reachability. The experimental procedures were similar to study 1, but we analyzed dyads of parents and children, in which each parent evaluated their son's or daughter's reachability.

### *3.4.1. Method*

#### *3.4.1.1.Participants.*

Thirty-seven adults (22 mothers and 15 fathers), with ages from 24 to 43 years-old (M=34.11, SD=3.88), with maximum reachability ranging from 194.6 cm to 245.5 cm (M=218.38, SD=13.31), and with normal or corrected-to-normal vision.

#### *3.4.1.2. Models.*

Thirty-seven children (21 boys and 16 girls), who were sons or daughters of the participants, with ages between 1.20 and 4.54 years-old (M=3.19, SD=0.96), and with maximum reachability between 92.2 cm and 138.6 cm (M=118.32, SD=14.06).

#### *3.4.1.3. Procedures.*

The same apparatus used in study 1 was used in this study. Each parent estimated their son's or daughter's reachability. The experimental procedures were similar to study 1.

#### *3.4.1.4. Data collection and analysis.*

The following variables were analyzed: estimation error, intrinsic error, AE, APE, and error tendency.

For the statistical analysis of perceiver's accuracy, the Wilcoxon test was used to compare AE and APE for the children and for the parents. Error tendency was analyzed through frequency distributions. Pearson correlation was employed to analyze the effect of children's body dimensions on their parent's estimations. The Spearman correlation was used to investigate the relationship between errors for self-reachability and for children's reachability.

### *3.4.2. Results*

Values of AE were similar in the estimation of children's reachability (M=6.40 cm, SD=4.49) and the observer's reachability (M=6.78 cm, SD=4.51), which represents a greater APE in the estimation of children's reachability (M=5.47%, SD=3.84%) than in the estimation of self-reachability (M=3.12%, SD=2.13%), due to adult's greater body dimensions. The APE for parent's reachability was significantly lower than the APE for their children's reachability (Z=-3.064, p=0.002).

To study the effect of children's body dimensions on their parent's estimations, the correlation between the ratio reachability/height of the children and their parent's estimation errors was analyzed. A significant negative correlation between this ratio and estimation errors (r=-0.337, p=0.042), and between this ratio and intrinsic errors (r=-0.392, p=0.016) was found. These results indicate that estimation errors and intrinsic errors tend to be positive in younger children (whose ratio reachability/height presents the smallest values) and negative in older children (whose ratio reachability/height presents the greatest values).

Most parents underestimated their own reachability (89.12% of underestimations and 8.11% of overestimations) and overestimated their son's or daughter's reachability (62.16% of overestimations and 8.11% of underestimations).

There were no significant correlations between the estimation of self-reachability and the estimation of children's reachability. The absence of correlation was verified in all the types of error (i.e., estimation error, intrinsic error, AE, and APE).

### *3.4.2. Discussion*

Although the AE values for the estimation of children's and parent's reachability were quite similar, the APE was significantly lower in the estimation of self affordances (i.e., parents) than in the estimation of other people's affordances (i.e., children). The error tendencies for self affordances (89.12% of underestimations) and for children's affordances (62.16% of overestimations) were also distinct.

The results that indicate a negative correlation between the proportionality ratio (reachability/height) of the children and estimation and intrinsic errors support the results of study 1. Although in study 2 most parents overestimated their children's action capabilities, the greatest overestimation errors occurred in the youngest children.

The errors in the perception of parent's self-reachability and their child's self-reachability were not correlated, indicating that a deeper knowledge of the model is not relevant to distinguish between egocentric and allocentric frameworks in the judgement of reachability.

**3.5. General discussion**

The findings of the two studies support Mark's (2007) statement that information about affordances is public and perceivable, whether for the actor or for other people, since adults were capable of predicting quite accurately their own reachability and children's reachability.

The accuracy of self-estimation was higher than the estimation of children's reachability, indicating that the perceptual experience leads to a finer attunement of self affordances. The better attunement to the environmental information that specifies our own affordances might have resulted from a process of education of attention (Jacobs & Michaels, 2007; Michaels, Arzamarski, Isenhower, & Jacobs, 2008). Our results suggest that the process of education of attention for children's affordances might also have occurred in the professional caregivers group, with daily professional experience with children, since their perceptual estimations were slightly more accurate.

In the present investigation, mean values for AE in reachability were similar to those in Fisher's first study (Fischer, 2003), that indicated mean errors of 6.75 cm for the short actor, and 10.10 cm for the tall actor. However, in study 2, with a greater number of observers, Fischer (2003) reported a smaller magnitude of AE (i.e., 3.15 cm for the short actor, and 3.27 cm for the tall actor).

The experimental procedures that we have adopted may explain the greater error magnitude that we reported in the two studies. In fact, we determined maximum vertical reaching height in a more functional and realistic manner than previous studies, since in most studies actors were not allowed to stand on tip-toes. The adoption of functional measurements is critical in terms of child safety because they create a more realistic experimental scenario about real world settings.

It is also important to note that in this investigation the point of observation in relation to the context varied between the evaluation of self affordances and children's affordances, since the observer was closer to the shelf when evaluating self affordances. We think that this methodological option represents the most common situation in real settings. Perceivers usually judge their own affordances in the place where they act, but that is usually not the case when judging other people's affordances. As Gibson (1979) stated, an observer can perceive the information available to another person without having to occupy his/her point of observation.

In study 1 there was a tendency to overestimate the youngest child's reachability, and in study 2 a negative correlation between children's proportionality ratio (reachability/height) and estimation and intrinsic errors was found. These results indicate that there is a greater overestimation tendency when evaluating children whose ratio reachability/height is smaller, that means, children with more distinct proportions than those of the adults. Even though the error magnitude in the estimation of these children's affordances was not influenced, the error tendency seems to have been affected.

The tendency to overestimate other people's affordances reported in the literature (Fischer, 2003) was not confirmed in the estimation of the older child's reachability by the inexperienced group. This may have damaging consequences, because the estimation of safe conditions by inexpert adults may lead to erroneous options concerning what children can or cannot do.

Adults that were more accurate in estimating their own reachability were not necessarily better in the estimation of children's reachability. This was true for all the groups of adults, which means that the level of experience that adults have with children, or the specific knowledge that they have of the child they are evaluating, does not affect the nature of the relationship between egocentric and allocentric frameworks. Our investigation indicates that the allocentric framework is independent of the egocentric framework, which contradicts the results of Ramenzoni et al. (2008a). However, there are significant methodological differences between our investigation and Ramenzoni's study (2008a), since in the present study estimations of reachability were not mediated by action, but they were the result of static perceptive estimations. The results of our investigation indicate that the processes of attunement to the information that specifies self affordances or other people's affordances are independent and probably result from different processes of education of attention.

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# 4. Adults' perception of children's height and reaching capability


### 4.1. Abstract

This study investigated the influence of some characteristics of the task, the model, and the observer, in the estimation errors of adults while judging children's affordances. One hundred and eighteen adults, divided in 4 height groups, estimated height and vertical reaching capability of 3 girls (3.55-, 4.74- and 7.06-years old), in the presence and in the absence of the model. Constant errors (CE) (estimation-real value), absolute percent errors (APE) (|1-estimation/real value|x100), and error tendency (underestimations, right judgments, or overestimations) were calculated. A model and a condition effect were verified on APE. APE for the younger model were greater than for the other models ($p<.001$), and APE in the absence of the model were greater than in her presence ($p<.05$). Generally, adults underestimated height (51.8% of underestimations vs. 32.3% of overestimations) and overestimated reachability (51.3% of overestimations vs. 37.7% of underestimations). The overestimation of reachability was more notorious for the younger model (62.3%), which might reflect adults' difficulty to consider the specificity of younger children's body proportions. Actually, the overestimation bias may suggest that adults perceive young children as on the basis of adult's geometrical proportions.


Keywords: children's affordances; visual perception; reaching.

### 4.2. Introduction

The visual estimation of other people's dimensions and capabilities is recurrent in daily life situations (e.g., height or weight estimation to buy clothes for children), and in many professional settings (e.g., height and weight estimation in intensive care units to adjust drugs dosage). Although people feel that perception is usually precise (Bridgeman & Hoover, 2008), studies suggest that the estimation of body dimensions (Bloomfield, Steel, MacLennan, & Noble, 2006; Hendershot et al., 2006), or movement boundaries of others (Fischer, 2003; Rochat, 1995) are often inaccurate.

The estimation of functional measures for other people may be framed in the broader question of the perception of affordances (Gibson, 1979), and more specifically the perception of other people's affordances (Mark, 2007; Rochat, 1995; Stoffregen, Gorday, Sheng, & Flynn, 1999). Gibson (1979) introduced the concept of affordance to describe the opportunities for action provided by the environment for an animal. Affordances are properties of the animal-environment system, since they represent a relation between the abilities of the animal and the features of the environment (Chemero, 2003; Stoffregen, 2003). To perceive an affordance means perceiving the environment in terms of one's action capabilities. Affordances perception might be related to one's dimensions in relation to a property of the environment (e.g., if an object is within our arm's reach we consider it "reachable"), this type of affordances has been called body-scaled affordances; or it might be related to one's behavior in relation to the environment (e.g., if we can run fast enough to catch a fly ball we consider it "catchable"), this type of affordances has been called action-scaled affordances (Fajen, Riley, & Turvey, 2009). However, not all affordances fit neatly in one of these two categories, and some affordances, such as reaching by jumping are determined by one's dimensions and capabilities (Fajen et al., 2009).

One interesting feature is that the information that specifies affordances, mainly body-scaled affordances, is public, so it might be available not only to the actor but also to an observer. As Gibson points out, the assertion "I can put myself in your position" (Gibson, 1979, p.200) is not a mere figure of speech, meaning that an observer can perceive the information available to another person, without having to occupy his/her point of observation. The question of whether an observer can use this public information to perceive another person's affordances has already been addressed by previous studies (Mark, 2007; Rochat, 1995; Stoffregen et al., 1999). These studies focused on the perception of adults' affordances on several different tasks and suggested that observers are able to use an egocentric framework while evaluating their own action capabilities, shifting to an allocentric framework when evaluating other people's capabilities (Mark, 2007; Rochat, 1995; Stoffregen et al., 1999). Even though the information about affordances seems to be public and perceivable, it is not always accurate. Some studies report errors of approximately 10% (Stoffregen et al., 1999) in the perception of other adult's action capabilities.

Errors in the perception of other people's affordances depend on task conditions. Task conditions such as the observer's perspective during evaluation (Gabbard, Ammar, & Rodrigues, 2005; Wagman & Malek, 2008; Wraga, 1999), the viewing conditions (Shim, Hecht, Lee, Yook, & Kim, 2009), the postural and kinetic constraints during task performance (Gabbard, Cordova, & Lee, 2007; Wagman & Malek, 2007, 2009), the exploratory activity (Mark, Jiang, King, & Paasche, 1999), and the action capabilities of the observer during estimation (Ramenzoni, Riley, Shockley, & Davis, 2008a), play a fundamental role in the estimation accuracy and the nature of bias effects. Other task conditions, such as the nature of the variable to be estimated or the information that is available during estimation deserve further investigation.

Regarding the nature of the estimated variable, the estimation accuracy for direct linear body dimensions, like body height, is more accurate than the estimation of inference based characteristics, such as body weight (Bloomfield et al., 2006; Determann et al., 2007). The estimation of simple morpho-functional variables, such as reaching capability, seems to be more accurate than the estimation of functional active variables that involve actions of higher complexity, such as a reach-and-jump task (Pepping & Li, 2005). The estimation of morphological variables has been addressed in medical settings (Bloomfield et al., 2006; Determann et al., 2007), but not in the scope of affordances perception. The relationship between the estimation of simple morphological variables (e.g., height) and estimations of morpho-functional variables (e.g., reachability) has not been previously investigated.

The information available during estimation is another important task constraint. Stoffregen et al. (1999) using real life situations and artificial kinematic displays verified that observers could perceive affordances for other as long as the actor-environment relations that define those affordances were preserved. The experimental designs have generally considered the visual presence of the model whose dimensions or affordances were estimated. A study on the estimation of head size (Bianchi, Savardi, & Bertamini, 2008) concluded that when visual information is provided, the overestimation of one's own head or of another person's head is reduced. The estimation of other person's capabilities in the absence of the model has not been addressed by previous studies. However, it is an appealing problem since in the absence of the model the direct perceptual confrontation of the model with the environment is not possible, and observers will probably have to rely on an indirect process of perception, based on their visual memory of the model's dimensions.

The characteristics of the model are also important for the perception of other people's affordances. Studies on the perception of body dimensions of passive subjects in medical settings (Kahn, Oman, Rudkin, Anderson, & Sultani, 2007; Uesugi et al., 2002) suggest that the estimation errors for less familiar models are more likely to occur. The estimation errors of infants and children with a small physical size also to be more frequent and of a greater magnitude (Uesugi et al., 2002). Adult's estimates also become significantly less accurate in underweight and obese patients (Kahn et al., 2007). The existing literature provides some information concerning the estimation of body dimensions, but the perception of affordances is a different topic; the relationship between the perception of body dimensions and the perception of affordances that rely on physical characteristics has not been thoroughly discussed.

The adult's estimation of a child's limits of action is a common example of affordances' detection, since parents and caregivers share the responsibility to manage the environments the children move in. The role of parents and educators in the management of environmental conditions has been widely reported in the literature about child safety and prevention of childhood injuries (Morrongiello, 2005), and the anticipation of action possibilities of the children is an important part of this task. In what concerns reachability, a wrong judgment of whether an object is within vertical reach of a child, might lead adults to place dangerous objects in places accessible to children. A few studies have addressed the issue of adult's perception of children's reachability (Cordovil & Barreiros, 2009, in press), indicating that adults with no experience dealing with children have a greater tendency to underestimate children's reachability (Cordovil & Barreiros, in press), and that the youngest children's reachability seems to be more frequently overestimated (Cordovil & Barreiros, 2009). It is not clear if the overestimation of the youngest children's reachability is only valid for functional variables, or if it is a consequence of an overestimation of morphological variables, such as height, because height estimations have not been considered in those investigations.

The height of the observer is an individual constraint that should also be taken into consideration. The relationship between other people's affordances and the viewing perspective of the observer was previously investigated in a study of vertical reaching perception for one's self and for others (Ramenzoni, Riley, Shockley, & Davis, 2008b). The results suggested that eye-height scaled optical information was used to evaluate affordances for others, and that taller observers exhibited larger errors when estimating the affordances for shorter models.

This study aims to analyze the influence of: the type of variable to be evaluated (i.e., morphological or morpho-functional); the condition of evaluation (i.e., present or absent); and the model's and observer's dimensions in the adults' estimations of children's height and reaching capability. Concerning the observer's accuracy, we expected that: a) the estimation errors for reachability would be greater than for height; b) the estimation errors in the absent condition would be greater than in the present condition; c) the estimation errors would be greater for the youngest and shortest model (child 1), and would be smaller for the eldest and tallest model (child 3); d) shorter adults' estimations would be more accurate than taller adults' estimations.

## 4.3. Method

### *4.3.1. Participants*

One hundred and eighteen adults (60 males and 58 females), with ages between 18.20 years and 40.07 years (M=23.21, SD=5.23), heights between 150 cm and 198 cm (M=171.9, SD=9.05), and with normal or corrected-to-normal vision, participated in this study as observers. Participants were divided into four groups according to their height: group 1 - participants with heights between 150 and 165 cm (N=32; M=161.22, SD=3.73); group 2 - participants with heights between 166 and 171 cm (N=29; M=169.21, SD=1.42); group 3 - participants with heights between 172 and 179 cm (N=29; M=174.52, SD=2.54); and group 4 - participants with heights between 180 and 198 cm (N=28; M=184.29, SD=4.56).

Previously to the data collection informed consent from the parents of the children and the observers that participated in the study were obtained.

### *4.3.2. Models*

The models were three girls between 3 and 7 years old. The anthropometric and functional characteristics of the models are presented in Table 4.1.

Table 4.1. Anthropometric and functional characteristics of the models.

| Child | Age (yrs) | Stature (cm) | Sitting height (cm) | Arm span (cm) | Maximum reachability (cm) |
|---|---|---|---|---|---|
| 1 | 3.55 | 92 | 52 | 91 | 117.8 |
| 2 | 4.74 | 113.5 | 59.5 | 110 | 146.6 |
| 3 | 7.06 | 121 | 64 | 115 | 156.2 |

The older model was 30 % taller than the younger, with an identical variation of the maximum reachability. The ratio of sitting height to stature, which is a good indicator of the children's body proportions (Bogin & Varela-Silva, 2010), was 56.52% in child 1, 52.42% in child 2 and 52.89% in child 3, indicating that child 1 was the most disproportionate when compared to adults, a natural consequence of her age.

### *4.3.3. Apparatus*

A shelf that could be raised or lowered in 1.6 cm intervals (from 25 cm to 188.2 cm) was placed in a well-illuminated room. A cylindrical toy (diameter - 3.5 cm; height - 6 cm) was placed on the shelf, and observers stood 6 m away from it. During observers' estimations the shelf was at the minimum height (i.e., 25 cm). The observers were instructed to mark with an erasable pen, on an aluminum beam behind them, the estimated height and maximum reachability of each child, in the presence and in the absence of the model.

*4.3.4. Procedures*

Height and maximum vertical reachability were determined for each model. Maximum vertical reachability was defined as the greatest height at which the model could take the toy out of the shelf, being allowed to stand on tip-toes and touch the shelf, but not to climb or jump to complete the task. To determine a maximum vertical reachability for each model, the shelf was adjusted starting from the vertical distance of the model with her arm extended, being raised 1.6 cm after each successful attempt and lowered 1.6 cm after each failure.

After filling in an individual form (indicating gender, birth date and height), observers were conducted to the experimental room. The model entered the room, stood near the shelf with her arms at the sides, and turned around for approximately 8 s so that the observer could see her walking and standing from the front, from behind and from both sides. The observers were instructed to look at the model, maintaining their standing position, and mark her height and maximum vertical reachability in that specific situation, as previously defined (i.e., they were informed that the child was allowed to stand on tip-toes and touch the shelf, but not to climb or jump to reach the toy). Each model was judged under two conditions: present and absent. In the present condition, the observer marked the model's height and maximum vertical reachability with the model still standing 50 cm aside the shelf. In the absent condition, the model left the room before the evaluation moment, and the observers were allowed to register their estimations 5 s after losing visual contact with the model. The marks on the aluminum beam were erased after each height and reachability estimation. Every observer evaluated all the 3 models' height and reaching capability in both conditions. The order of presentation of the models and of the conditions (i.e., present and absent) was randomized.

*4.3.5. Data Collection and Analysis*

Constant errors (CE) (estimation-actual measure), absolute percent errors (APE) (|1-estimation/actual measure|x100), and error tendency (i.e., frequency of underestimations, accurate estimations, or overestimations) were calculated. Constant error is a signed error, negative values expressing underestimations and positive values expressing overestimations. The analysis of the group's CE gives an indication of the overall bias. Absolute percent error (APE) is the amount of error in percentage of the real reachability of the model. This variable is a good indicator of perceivers' accuracy since, it is scaled to the model, and as it is expressed in absolute value, underestimations do not compensate overestimations when considering the mean group's value. Smaller values of APE indicate a greater perceiver's accuracy. For the calculation of error tendency, estimations were considered accurate if estimation error was equal to or less than 1.6 cm (i.e., the minimal interval between two possible heights of the shelf). Estimation errors greater than that value were considered underestimations (estimation - real value < - 1.6 cm) or overestimations (estimation - real value > 1.6 cm).

A repeated measures ANOVA was conducted for the data analysis of perceivers' accuracy (APE). Model (3 levels), type of variable (2 levels), and condition (2 levels) were entered as within-subjects variables; and the observer's height group (4 levels) was entered as a between-subjects factor. Bonferroni's post hoc tests were applied when necessary. The Greenhouse-Geisser correction was used in case of violations of sphericity. Descriptive statistics of CE and APE were presented and frequency distributions and chi-squares tests ($\chi^2$) were adopted to analyze error tendency. Statistical significance was set at $p < 0.05$ level.

## 4.4. Results

### *4.4.1. Constant error*

Constant error, which represents the group's overall accuracy and bias varied between -38.00 cm and 43.20 cm (M=-.0005, SD=10.50). Results of CE for height and for reachability according to model and condition are presented in Fig. 4.1.

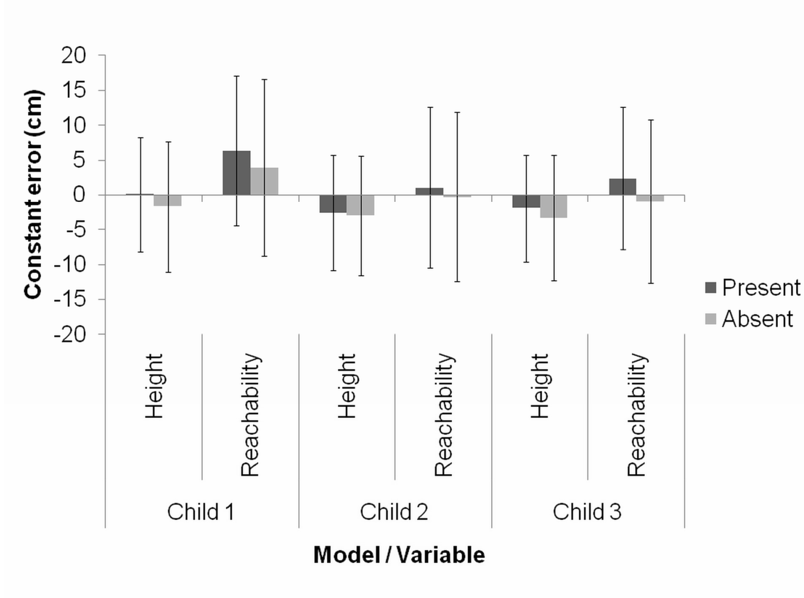


Fig. 4.1. Mean constant errors for height and reachability of each model, in present and absent conditions. Error bars indicate standard deviations.

Mean values of CE in Fig. 4.1 should be analyzed with caution since they represent the overall group's accuracy. A CE of about 0 cm, as it happened in the height estimations of child 1 in present condition (M=0.07, SD=8.22), does not mean the perceivers were accurate, as it is confirmed by the standard deviation value. In this case what probably happened was that the percentage of observers that underestimated the height of child 1 was similar to the percentage that overestimated it, and the magnitude of the overestimations and the underestimations was probably also similar.

*4.4.2. Absolute percent error*

Absolute percent error, which represents perceivers' accuracy, varied between 0% and 36.7% (M=6.68%, SD=5.36). Results of APE according to child, type of variable and condition are depicted in Fig. 4.2.

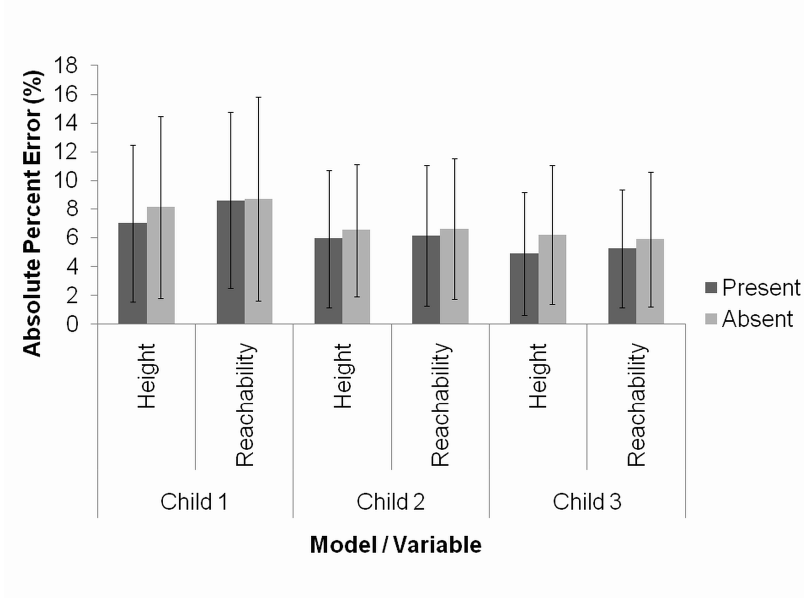


Fig. 4.2. Mean absolute percent errors for height and reachability of each model, in present and absent conditions. Error bars indicate standard deviations.

The repeated measures ANOVA revealed significant main effects of child ($F(2,195)=21.324$, $p<.001$, $\eta^2_p=.158$) and condition ($F(1, 114)=5.870$, $p=.017$, $\eta^2_p=.049$).

Bonferroni's post hoc results indicated that APE for child 1 (M=8.14, SD=6.30) was significantly greater than for child 2 (M=6.32, SD=4.80) ($p<.001$) and than for child 3 (M=5.58, SD=4.50) ($p<.001$). APE for child 2 was greater than for child 3, but results just failed to reach significance ($p=.057$). APE in the absent condition (M=7.04, SD=5.57) was greater than in the present condition (M=6.33, SD=5.13) ($p=.018$).

The effect of type of variable ($F(1,117)=1.41$, $p=.237$, $\eta^2_p=.012$) and all the interactions were not significant. Observer's height group did not influence APE ($F(3,114)=1.717$, $p=.167$, $\eta^2_p=.043$).

*4.4.3. Error tendency*

Error tendency for height was significantly different than error tendency for reachability ($\chi^2(2)=52.19$, $p<.001$). Height was generally underestimated (51.8% of underestimations, 15.8% of accurate estimations and 32.3% of overestimations) and reachability was generally overestimated (37.7% of underestimations, 11.0% of accurate estimations and 51.3% of overestimations).

The condition of evaluation also influenced error tendency ($\chi^2(2)=10.67$, $p=.005$). There were more overestimations in the present condition than in the absent condition (present condition: 40.5% of underestimations, 15.0% of accurate estimations and 44.5% of overestimations; absent condition: 49.0% of underestimations, 11.9% of accurate estimations and 39.1% of overestimations).

Results of error tendency for the height and reachability of each model in present and absent conditions are depicted in Fig. 4.3.

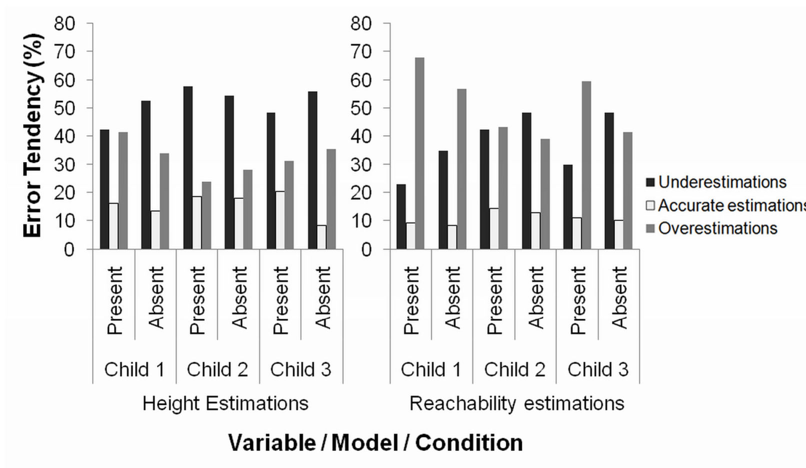


Fig. 4.3. Error tendency for the height estimations (left) and for the reachability estimations (right) of each model in present and absent conditions.

Error tendency for judging height was similar for the 3 models (i.e., a greater percentage of underestimations, even though that tendency is not clear for the height of child 1 in the present condition). Reachability was generally overestimated, except for the estimations of models 2 and 3 in the absent condition, where an underestimation tendency occurred. There was a notorious tendency to overestimate the reachability of the shorter model, in both conditions.

The relationship between height and reachability and between the prediction of height and of reachability is presented in Table 4.2.

Table 4.2. Real Values and Mean and Standard Deviations of Reachability-Height (R-H) Estimations, for the 3 Models, in Present and Absent Conditions.

| Model | Condition | R-H (cm) Estimation M (SD) | R-H (cm) Real value |
|---|---|---|---|
| Child 1 | Present | 32.04 (7.86) | 25.8 |
| | Absent | 31.37 (8.40) | |
| Child 2 | Present | 36.69 (8.83) | 33.1 |
| | Absent | 35.83 (9.08) | |
| Child 3 | Present | 39.49 (8.24) | 35.2 |
| | Absent | 37.57 (9.56) | |

Data from Table 4.2 emphasizes the adults' tendency to overestimate children's reachability, especially for the smallest child. Although child 1 could only reach 25.8 cm (i.e., plus 28%) above her height, adults' mean predictions varied between 31.37 cm in the absent condition and 32.04 cm in the present condition, which represent an increase of 35% of her height. The differences between real and estimated values tended to decrease as the height of the child increased and as the child's proportions became more similar to the adult's.

**4.5. Discussion**

The results of observer's accuracy (depicted by APE) in our study showed that participants were generally capable of perceiving children's action capabilities, confirming that information about affordances for other people is public (Gibson, 1979) and perceivable (Mark, 2007; Stoffregen et al., 1999), even when people evaluate models with physical dimensions and action capabilities quite distinct from their own.

However, as we hypothesized, adult's accuracy in predicting children's dimensions and capabilities depends on some task constraints and on the dimensions of the model.

Contrary to our initial expectations estimation errors for reachability were not significantly greater than for height. Previous studies indicated that morpho-functional variables were easier to predict than functional active variables of higher complexity, such as a reach-and-jump task (Pepping & Li, 2005). The comparison between estimations of simple morphological variables, such as height, and estimations of simple morpho-functional variables, such as reaching without jumping, had not been previously studied. The results of the present study indicate that adult's are equally accurate in predicting these two types of variables, probably because reaching without jumping is a clearly body-scaled affordance, which implies that most of the information that specifies the reaching affordance is available for the observer when he/she looks at the child and at the shelf. Even though there were no differences in absolute percent errors for height and reachability estimations, error tendency was clearly different, since height was generally underestimated while reachability was generally overestimated. These opposite tendencies were also noticeable in the results of CE. Overestimation of reachability has been reported in previous literature (Carello, Grosofsky, Reichel, Solomon, & Turvey, 1989; Fischer, 2003, 2005; Gabbard, Ammar, & Lee, 2006; Gabbard, Cacola, & Cordova, 2008; Pepping & Li, 2000; Rochat & Wraga, 1997). Results of this study indicate that, when estimating children's capabilities, this bias is probably related to an overestimation of the model's arm, and not related to a general overestimation of the model's dimensions, because height was generally underestimated. To our understanding, the more frequent overestimation of reachability might reveal an inability to consider children's specific body proportions when evaluating functional measures. The ratio reachability/height is smaller in children than in adults. The adults' tendency to overestimate this ratio, considering children's arms to be longer than they actually are, might be described in Leonardo da Vinci's words: "For this is reckoned a common fault in painters, to delight in the imitation of themselves" (da Vinci, 1651 / 2002, p. 185).

As hypothesized, and despite the small value of the effect size, estimation errors in the absent condition were greater than in the present condition. These results support the idea that affordances' estimation is easier when the relevant actor-environment relations are preserved (Stoffregen et al., 1999), and is an argument in favor of Gibson's theory of direct perception. When observers had to rely on their visual memory of the model's dimensions (i.e., absent condition), their perception was less accurate than when they could directly perceive the actor-environment relationship (i.e, present condition). Theoretically, these results do not exclude the possible indirect perception alternative approach. The reduced accuracy that was observed in the absent condition might be explained by arguing that memory reconstruction processes are not as accurate as the direct estimation of children's dimensions. Error tendency was also affected by the estimation condition. Overestimations were greater in the present condition as reported by previous literature

(Bianchi et al., 2008). In the absent condition most adults underestimated the reachability of models 2 and 3. This underestimation tendency might be a problem in terms of child safety, since adults might place dangerous objects at what they consider to be unreachable heights for children, which are actually reachable.

Concerning the dimensions of the model, we had predicted that estimation errors would be greater for the child 1 and smaller child 3. In fact, the APE for height and for reachability seemed to decrease with the height of the model. The main effect of child also had a small effect size. However, values of APE for the shorter model were significantly greater than for the taller children. APE values for the taller model were also smaller than for child 2 but they failed to reach significance (p=.057). The differences in APE between child 2 and child 3 might have not been as notorious as the differences between child 1 and the other models due to the children’s dimensions. In fact, differences in height and range of reach were about three times greater between model 1 and 2 as compared to model 2 and 3. This might be considered a limitation of the present study. Previous studies on the perception of body dimensions (Kahn et al., 2007; Uesugi et al., 2002) referred that the estimation accuracy diminishes when judging atypical models. In this study, adults were more precise when evaluating the taller children, which might indicate that their judgment is based on an internal reference to evaluate other people’s affordances.

A previous study with the same vertical reachability task performed by adults (Cordovil & Barreiros, 2009) revealed that an average adult of 166.1 cm has a reachability of 218.5 cm, being able to reach objects 52.4 cm above his/her height (on tip-toes but without climbing or jumping). The corresponding value for child 1 in this study was about 25.8 cm, which is half of the observed value for an average adult. These data reflect the differential growth rates of specific body parts that result in changes in the body’s appearance as a whole. Therefore, children have different proportions from adults, with larger heads and shorter limbs relatively to their body size. The tendency to overestimate younger children’s reachability might reflect a difficulty for the adults to consider children’s inherent body proportions, considering them as “small adults” based on a proportional frame of reference for adults. Perceptual re-scaling of children may be based upon an adult’s body proportions model. This adult-like model was also noticeable in the first paintings of children: “When Christ first appeared in painting as an infant the posture and body scaled proportions are more adult-like” (Fogel, 2004, p. 737).

The proportionality hypothesis is probably part of the explanation for the least accurate estimations when evaluating the younger model. However, other explanations, such as the sheer difference in height between the 3 models, might also have influenced the adults' estimations. During growth height and reachability co-vary, and for that reason it is nearly impossible to determine whether estimation errors are a function of absolute height or of body proportions. This issue could be further explored in future studies, maybe in virtual environments, where the manipulation of human proportions does not have to reflect natural biological limitations of living organisms.

Finally, in what concerns the observer's dimensions our initial hypothesis was not verified since shorter adults were not more accurate than taller adults when predicting children's height and reachability. The fact that the observer's height had no effect in APE contradicts some results of the previous literature (Ramenzoni et al., 2008b). However, the height differences between observers and models in Ramenzoni et al.'s study were not as notorious as in the present study since both models and observers were adults. The great discrepancy between the adults' and the children's heights seems to have equally affected shorter and taller adults in our study. Other individual constraints, such as the observer's experience in dealing with children (Cordovil & Barreiros, 2009, in press) seem to have a greater influence in the observer's accuracy than the observer's height.

The evaluation of children's action capabilities by adults is of fundamental importance and has received little attention so far. Our study indicates that some constraints, such as the characteristics of the model or the evaluation conditions, might be essential when adults organize the environments where children move in.

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# 5. Perceiving children's affordances: retuning estimation following one single observation


### 5.1. Abstract

The effects of one single observation in adult's perception of a child's affordances in 3 tasks were investigated. Forty adults (M=21.47 yrs, SD=2.49), divided in two groups made judgements about the reachability of one 5-year-old boy, used as a model. Both groups made two estimations of standing reachability, reach-and jump and step length. The experimental group observed the child performing the task between first and second estimations, but the control group did not. Absolute percent errors (|1-estimation/real value|x100) and error tendency (underestimations, right judgments, and overestimations) were calculated. Observers were significantly less accurate in predicting the child's maximum step length than in predicting his reachability in the other two tasks. Predictions of standing reachability were initially quite accurate. The observation of a single trial reduced error magnitude for the reach-and-jump and step length tasks in about 50%. Observation of one trial was enough to significantly adjust perceivers' estimations, but only if the first estimation was poor. An absolute error of 5 cm persisted after one-trial observation.


Keywords: children's affordances; reachability; one-trial observation; attunement.

### 5.2. Introduction

A growing body of research has demonstrated that people can perceive their own affordances (e.g., E. J. Gibson et al., 1987; Ishak, Adolph, & Lin, 2008; Mark, 1987; Warren, 1984; Warren & Whang, 1987). The perception of other people's affordances has not been as widely studied as the perception of self affordances, but there are good arguments to believe that humans can do it with reasonably accuracy (Mark, 2007; Rochat, 1995; Stoffregen, Gorday, Sheng, & Flynn, 1999).

Studies on the perception of other people's affordances have underlined that the information that specifies affordances is public (Mark, 2007), and that two observers can detect the same information without necessarily having the same point of observation. As Gibson points out "I can put myself in your position…And if so, we can both perceive the same world." (J. J. Gibson, 1979, p. 200). Affordances are relations between the abilities of the animal and features of the environment (Chemero, 2003), and in that sense they can be "externally" perceived by observers. The pickup of environmental information that specifies action capabilities for others, allows observers to predict other people's affordances, using an egocentric framework when evaluating their own capabilities shifting to an allocentric framework when evaluating other people's capabilities (Cordovil & Barreiros, 2009; Mark, 2007; Rochat, 1995; Stoffregen et al., 1999).

However, perceiving affordances is more than merely perceiving relations. It also involves the information that guides the action and the intention or goal of the action (Michaels, 2003). The perception of affordances for other persons implies the perception of these elements, anticipating the other's actions and intentions. The perception of other's actions and intentions is essential in many daily live situations, such as in having the possibility to prevent a child's dangerous action. The adult's estimation of a child's action limits is a common example of affordances' detection. The characteristics of the child and the characteristics of the observer may be responsible for some variation in the accuracy of the estimation. For instance, the experience in dealing with children seems to increase the accuracy in the estimation of children's reachability (Cordovil & Barreiros, in press).

The increased accuracy in judging affordances implies paying more attention to relevant cues in the environment and to decrease attention to irrelevant cues. This process of education of attention (J. J. Gibson, 1979) or attunement (Fajen & Devaney, 2006; Wagman, Shockley, Riley, & Turvey, 2001), is achieved trough practice, and the effects of practice are facilitated if feedback or knowledge of results are provided (Wagman et al., 2001). The process of attunement is essential but not sufficient for perceptual judgments to be accurate; besides learning to attend to the right informational variable, observers need to be correctly scaled to the detected information, that is a process of calibration (Bingham & Pagano, 1998; Fajen, Riley, & Turvey, 2009; Jacobs & Michaels, 2006; Mark, 1987; Mark, Balliett, Craver, Douglas, & Fox, 1990; Withagen & Michaels, 2005). Mark (1987) showed that observers were able to retune specific accurate action boundaries under conditions of artificially changed body dimensions, following a very small amount of practice. The actions necessary to retune perception might be different from the action to be performed, whether observers are judging self affordances (Mark et al., 1990) or other people's affordances (Ramenzoni, Riley, Davis, Shockley, & Armstrong, 2008). Action is crucial for the tuning of actor and environment, but it is possible that the amount of practice that is needed to retune perception may be very small.

Plus, the amount of practice might also be dependent on the nature of the task to be perceived, and some affordances may be more difficult to predict than others. The estimation of functional simple variables, such as reaching capability, is more precise than the estimation of functional active variables that involve actions of higher complexity, such as a reach-and-jump task (Pepping & Li, 2005; Ramenzoni, Riley, Davis et al., 2008). According to Fajen et al. (2009) two major types of affordances have been studied by previous literature: body-scaled and action-scaled affordances. In body-scale affordances the individual's dimensions in relation to a property of the environment determine whether an action is possible (e.g., if an object is within our arm's reach we consider it "reachable"). In action-scale affordances it is one's behavior in relation to the environment that determines whether an action is possible (e.g., if we can run fast enough to catch a fly ball we consider it "catchable"). Some affordances do not fit neatly in one of these two categories. For instance, maximum reach-and jump, or maximum step length, are determined by one's dimensions and capabilities. When considering the evaluation of other person's affordances, body-scale affordances are probably easier to predict than action-scaled affordances because the actor's dimensions are visible to the observer whereas the actor's capabilities are not.

In this study the adult's perception of a child's affordances was investigated, in a standing reach task, a reach-and-jump task, and a maximum step length task. The effect of one-trial observation was analyzed in the three tasks. We hypothesized that (1) observers would be more accurate in predicting body-scaled affordances (i.e., the child's standing reachability) than affordances dependent on action and body-scale (i.e., the child's reach-and-jump and step length), and (2) that after one trial observation the perceivers' accuracy would increase in the three tasks.

## 5.3. Methods

### *5.3.1. Participants*

Forty adults (19 males and 21 females) between 18- and 28-years-old (M=21.47 yrs, SD=2.49) and with normal or corrected-to-normal vision, participated in this study as observers. Participants were randomly assigned to the experimental (n=20; 10 males and 10 females) or control (n=20; 9 males and 11 females) groups.

*5.3.2. Model*

One boy, 5.74-years-old, with a standing reachability of 140 cm, a reach-and-jump reachability that varied between 156 and 162 cm (M=160.12, SD=1.40), and a maximum step length that varied between 61 and 82 cm (M=73.20, SD=5.14).

*5.3.3. Apparatus*

Perceivers made judgments about how high the child could reach a laser light point that was displayed in a wall (standing reach and reach-and jump tasks) or in the floor (step length task).

The light point was created by a laser pointer attached to an adjustable tripod in a way that one of the experimenters could easily heighten it (i.e., move it up in the vertical reaching tasks and move it forward in the step length task) or lower it (i.e., move it down in the vertical reaching tasks and move it back in the step length task). The ascending / descending order was counterbalanced over all participants. The experimenter would raise or lower the point light until the perceiver told her to stop. Perceivers were allowed to fine-tune their responses until satisfied. The participants kept their eyes closed during the measurement of estimation error. The wall that the participants were facing in the standing reach and jump-and-reach tasks, and the floor and walls in the step length task, were covered with homogeneous white paper to remove any visual references on the surface.

*5.3.4. Procedure*

Maximum standing reachability was defined as the greatest height at which the child's dactylion would touch the wall by a frontal one-arm overhead reach with both hells on the ground. Maximum jump-and-reach reachability was defined as the greatest height at which the child's dactylion would touch the wall by a jump up with a frontal one-arm overhead reach. Maximum step length was defined as the greatest distance at which the child's heel would touch the ground in a step that would afford continuing walking.

Estimations for the vertical reaching tasks were made with participants (one at a time) standing at their own foot's distance of the wall, next to the child (who stood at his foot's distance of the wall). For the step length task, participants stood side-by-side with the children. After the estimations the child's dactylion or the child's tennis shoe's hell were painted with ink and the real values of reachability for each task were determined. For the reach-and jump and for the step length tasks, the child was instructed to perform the task twice and the highest value was considered. After each measure the marks were erased from the plastic paper so that no visual cues were left for the next estimation (i.e., estimation after the trial). Participants were allowed to look at the marks the child made on the wall or on the floor before they were erased. After the trial, participants were asked to indicate how high the child had reached in each task. Participants in the control group also estimated child's affordances twice, but were not allowed to observe the child's actions between observations. Task order was counterbalanced among participants. In total the experiment took approximately 15 minutes for each participant, and the data were collected in four different days so that it was possible to keep the child motivated.

*5.3.5. Data collection and analysis*

Absolute percent errors (APE) (|1- estimation/actual measure|x100), and error tendency (i.e., frequency of underestimations, right judgments, and overestimations) were calculated. Absolute percent error is the amount of error in percentage of the real reachability of the actor. This variable is a good indicator of perceivers' accuracy but not of the under / over estimation bias. For the calculation of error tendency, estimations were considered accurate if estimation error was ≤ 1 cm, underestimations if estimation - real value < - 1 cm, and overestimations if estimation - real value > 1 cm.

To compare differences in APE and analyze possible interactions, a repeated measures ANOVA with Task (standing reachability, reach-and-jump, and step length) and Estimation (first, second) as within-subjects factors, and Group (experimental, control) as between-subjects factor was conducted. Bonferroni's post hoc tests were applied when necessary. The Huynh-Feldt correction was applied in case of violations of sphericity. To analyze error tendency, frequency distributions and chi-squares tests ($\chi^2$) were adopted. Statistical significance was set at $p < 0.05$ level.

**5.4. Results**

APE mean values and standard deviations in the three tasks, for the experimental and the control groups, in first and second estimations are depicted in Fig. 5.1.

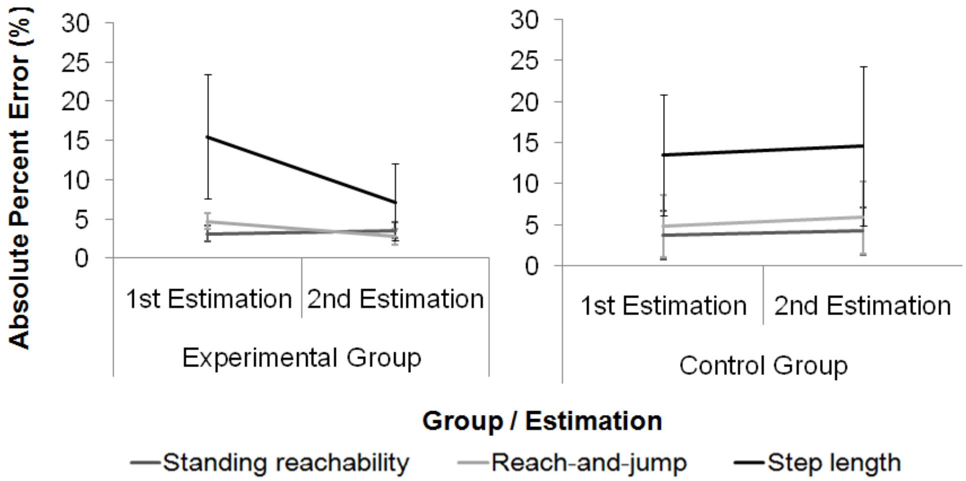


Fig. 5.1. Absolute percent error in first and second estimations for the 3 tasks (standing reachability, reach-and-jump, and step length) in the experimental and control groups. Participants in the experimental group saw the child's actions before second estimation. Error bars indicate standard deviation.

The analysis of variance revealed significant Task and Estimation main effects on APE. There were also Estimation x Group, Task x Estimation, and Task x Estimation x Group significant interactions. The Group effect and the Task x Group interaction were not significant.

The main effect of Task, $F(1, 57) = 60.548$, $p<.001$, $\eta^2_p= .614$, indicates that APE in the step length task (M=12.71, SD=8.21) was significantly greater than in the standing reachability (M=3.67, SD=2.74) ($p<.001$) and than in the reach-and-jump (M=4.56, SD=3.69) ($p<.001$) tasks. Differences in APE between the standing reachability and the reach-and-jump tasks were not significant ($p=.361$). The effect of task was identical in the experimental and the control groups since the Task x Group interaction was not significant, $F(1, 57) = .675$, $p=.472$, $\eta^2_p=.017$.

The main effect of Estimation, $F(1, 38) = 7.786$, $p=.008$, $\eta^2_p=.170$, indicated that APE was greater in the first (M=7.58, SD=7.06) than in the second estimation (M=6.38, SD=6.43). However, this main effect should be interpreted with caution because it is group dependent. The Estimation x Group interaction, $F(1, 38) = 23.466$, $p<.001$, $\eta^2_p=.382$, indicated that APE in the experimental group was greater in the first estimation (M=7.78, SD=7.48) than in the second estimation (M=4.50, p=4.04). This was not the case in the control group.

The Task x Estimation interaction, $F(2, 63) = 6.298$, $p=.002$, $\eta^2_p=.203$, revealed that differences in APE between the first and the second estimation were more notorious in the step length task (first estimation: M=14.52; SD=7.62 / second estimation: M=10.90, SD=8.47), than in the standing reachability task (first estimation: M=3.43; SD=2.57 / second estimation: M=3.92, SD=2.92) or in the reach-an-jump task (first estimation: M=4.79; SD=3.54 / second estimation: M=4.33, SD=3.85).

The interaction Task x Estimation x Group, $F(2, 63) = 7.701$, $p=.002$, $\eta^2_p= .169$, indicated that differences in APE between the experimental and control groups were more notorious in the second estimation of the reach-and jump and of the step length tasks (see Fig. 5.1). Actually, post-analysis revealed significant differences in APE between the second estimation of the two groups, for the reach-and jump ($t(30)=-2.801$, $p=.009$) and step length ($t(28)=-3.067$, $p=.005$) tasks. In these tasks, APE in the experimental group had a reduction of about 50% between the first and the second estimation (reach-and-jump: 4.70% to 2.76%; step length: 15.51% to 7.17%), whereas APE in the control group augmented (reach-and-jump: 4.89% to 5.90%; step length: 13.53 to 14.62%). Experimental and control groups had similar accuracy levels in the 3 tasks' first estimations and in the second estimation of the standing reachability. These results indicate that observing the child's action led to estimation adjustments only in the tasks with a low initial accuracy. The initial estimation of the standing reachability task was quite accurate (APE: M=3.14%, SD=2.14), so the one trial observation did not improve that accuracy (APE: M=3.57, SD=2.58).

In what concerns error tendency, results are presented in Fig. 5.2.

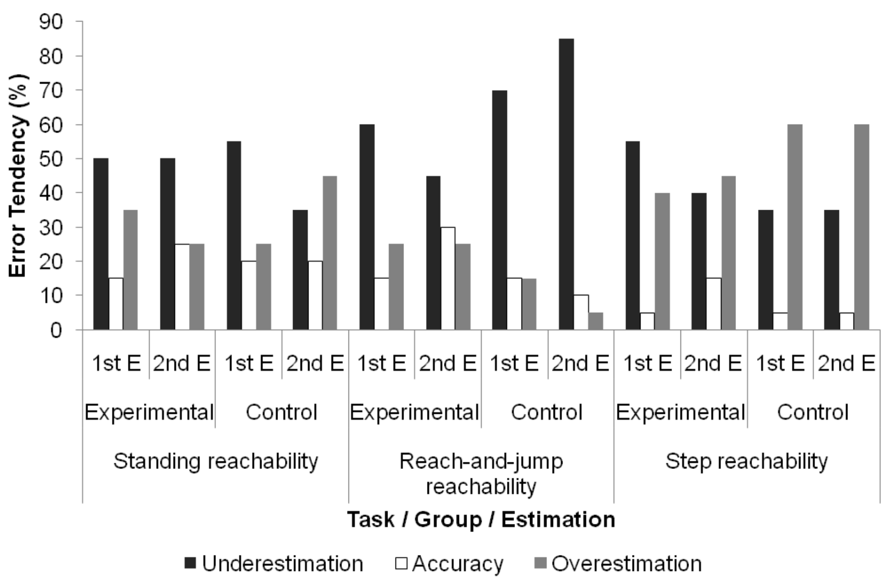


Fig. 5.2. Percentages of error tendency, in the three reachability tasks, for the experimental and the control groups, in first (1st E) and second (2nd E) estimations.

Observers in our study had slight tendency to underestimate the child's capabilities in the standing reachability and the reach and jump tasks (see Fig. 5.2). The underestimation of a child's reachability is a major concern in terms of child safety, since it might lead adults to place dangerous objects within reach of the child without realizing it. However, the observation of one trial with knowledge of results decreased the amount of underestimations (from 55% to 35% in the standing reach task, and from 60% to 45% in the reach-and-jump task) and improved the frequency of accurate estimations (from 15% to 25% in the standing reach task, and from 15% to 30% in the reach-and-jump task) in the experimental group. These results support previous studies that have mentioned a greater underestimation tendency of inexperienced observers in the evaluation of children's affordances when compared to experienced observers (i.e., professional caregivers or parents) (Cordovil & Barreiros, in press). However, despite the slight adjustments in the error tendency between the first and the second trial, the differences in error tendency between groups were not significantly different for first ($\chi^2(2)=.524$, $p=.770$) and second estimations ($\chi^2(2)=1.783$, $p=.410$) of the standing reachability task. The adjustments in the reach-and-jump task had a greater effect since differences in error tendency between groups were not significant in the first estimation ($\chi^2(2)=.654$, $p=.721$), but they were significant in the second estimation ($\chi^2(2)=7.128$, $p=.028$). The absence of knowledge of results between first and second estimations led observer in the control group to increase their underestimation tendency (from 70% to 85%). This result is in accordance with previous studies that mention a quite conservative tendency in judging self ability to reach-and-jump (Pepping & Li, 2005; Ramenzoni, Riley, Davis et al., 2008) and other's ability to reach-and-jump (Ramenzoni, Riley, Davis et al., 2008).

There was not a clear error tendency in the first estimation of the child's step length, since the experimental group had a slight underestimation tendency (55% underestimations) and the control group had a slight overestimation tendency (60% overestimations) (Fig. 5.2). The error tendency results in the control group did not change between first and second estimations. In the experimental group, the effects of one-trial observation of step length in error tendency were similar to the ones observed in the two vertical reaching tasks: there was a decrease in the underestimation tendency (from 55% to 40%) and an increase in the frequency of accurate estimations (from 5% to 15%). The differences in error tendency between groups were not significantly different for first ($\chi^2(2)=1.689$, $p=.430$) and for second estimations ($\chi^2(2)=1.495$, $p=.473$). Differences between the two groups in the second estimation of this task were notorious in error magnitude but not in error tendency.

**5.5. Discussion**

The findings of this investigation support the idea that one trial observation is enough to significantly adjust perceiver's estimations in some tasks.

In accordance with previous studies (Bloomfield, Steel, MacLennan, & Noble, 2006; Determann et al., 2007; Pepping & Li, 2005) some affordances were more difficult to predict than others. However, the initial hypothesis that observers would be more accurate in predicting body-scaled affordances than affordances dependent on action and body-scale was only partially verified. Unlike previous studies (Pepping & Li, 2005; Ramenzoni, Riley, Davis et al., 2008), participants in our study judged the child's action boundaries for the standing reach and for the reach-and-jump task with similar levels of accuracy. These differences in results might be explained by methodological differences between the three studies: i) Pepping and Li (2005) analyzed self affordances whereas we analyzed the perception of a child's affordances; ii) although Pepping and Li (2005) analyzed reaching as a proportion of each individual's actual reach, they did not analyze values of absolute percent errors as we did; iii) Ramenzoni (2008) verified that observers could estimate other adult's reach-and-jump with only slightly less accuracy than they could perceive his standing-reachability. The question whether reach-and-jump affordances are easier to perceive in children than in adults might be further investigated.

In the present study, predictions of step length were significantly less accurate than predictions of both measures of vertical reachability. The greater difficulty in predicting the step length of the child might be related to the nature of the task proposed. To predict the greatest distance at which the child's heel would touch the ground, in a step that would afford continuing walking, implies knowledge about the child's body dimensions and flexibility in a task that is not actually maximal, because the step should afford continuing walking. The reach-and-jump task was also a dynamical task, which implied body dimensions and strength, but the child was told to jump as high as he could. The step length task is also the least common of the three tasks for children in real live and this fact might have led to a more difficult prediction. When children want to cross gaps that are close to their maximum action capabilities they usually jump instead of stepping over and continue walking.

In the standing reachability task, a simple functional variable mostly dependent upon the child's body dimensions, the initial estimation was quite accurate, so the adjustments after one-trial observation were very small. Therefore, our second hypothesis, which predicted that after one trial observation the perceivers' accuracy would increase in the three tasks, was also only partially truth. In the more dynamic tasks (i.e., the reach-and-jump task and the step-length task), one-trial observation significantly reduced error magnitude in about 50%. However, mean absolute errors (i.e., |estimation-actual measure|) of about 5 cm persisted in the experimental group after one trial observation (i.e., 5.00 cm for the standing reach task, 4.40 cm for the reach-and-jump task, and 4.98 cm for the step length task). Due to the design of this study, the persistence or non persistence of the adjustment in perceivers' estimations was not investigated. However, the observation of one trial seems to have shifted the informational variables in which the perceivers relied on. After the trial, perceivers were more accurate probably because they were more attuned to the relevant properties in the environment that specified affordances. The question whether this momentary improvement leads to a more permanent process of perceptual learning should be investigated in future studies.

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# 6. Retrieving a toy from a swimming pool: parent's perception of their child's reachability in a risk scenario


## 6.1. Abstract

Some children fall in the water and might drown while trying to catch toys in swimming pools. Parental supervision is fundamental in water environments. However, little is known about children's behavior and parent's estimation of children's capabilities in this specific situation. Seventy six parents of 1 to 4 year-olds were asked to make a prior estimation of their children's behavior and action limits in a task that consisted in retrieving a toy out of the water. The action modes used for reaching, accuracy of estimation, absolute error, and error tendency were investigated. Several morphological variables, walking experience and swimming program experience, were analyzed as predictors of maximum and estimated maximum reachability. Most children sat to retrieve the toy out of the water and fell in while attempting to grasp beyond their reachability limits. Nearly 80% of the parents correctly predicted their child's behavior when the toy was unreachable. Parents were cautious in predicting their child's maximum reachability (more than 50% of underestimations). Mother's had a higher rate of adjusted estimations than fathers. The prediction of children's capabilities was partially based on body dimensions and proportions. Our results illustrate the importance of adult supervision around water environments, and underline the need to remove toys from the pool and surrounding area immediately after use.


*Keywords:* drowning; infants; children; parental supervision.

## 6.2. Introduction

Drowning is the second leading cause of child unintentional injury death worldwide (Peden et al., 2008), with the highest rates among boys, under five years of age (Peden et al., 2008; Peden & McGee, 2003; Vincenten, 2004). In the United States, drowning is the top leading cause of unintentional injury death among children 1 to 4 years old (Borse et al., 2009). High income countries children in this age group are most likely to drown in swimming pools (Brenner et al., 2003; Quan, Gore, Wentz, Allen, & Novack, 1989). Most young children who drowned in pools were last seen in the home, were in the care of one or both parents, and had been out of sight less than five minutes (Present, 1987). The inexistence of adequate protection barriers, as well as inadequate supervision, has been considered major risk factors in children's drowning (Blum & Shield, 2000; Cordovil, Barreiros, Vieira, & Neto, 2009).

The Centers for Disease Control and Prevention (CDC, 2004) underline the importance of supervision, and recommend the removal of floats, balls and other toys from the pool and surrounding area immediately after use, because the presence of these toys may encourage children to enter the pool area or lean over the pool and potentially fall in. When safety barriers and supervision fail, the presence of toys in the water seems to be a risk factor for drowning. However, we found no previous studies addressing this issue.

Studies on drowning have focused mainly on analyzing data relative to the victims' characteristics (e.g., age, gender, socio-economic status, swimming ability), the place of occurrence, the safety conditions, and the time of occurrence (Peden et al., 2008). The literature analyzing risk-taking behaviors at swimming pools is scarce (Schwebel, Simpson, & Lindsay, 2007). In the present study we intend to fill this gap by analyzing a specific risk-taking behavior (i.e., trying to reach a toy in the swimming pool), which has been referred as a drowning risk factor (CDC, 2004).

This investigation had four primary objectives. First we sought to categorize children's actions to catch a toy in the water from the swimming pool border. Second, we sought to quantify the number of children who would jump or fall in the water to reach the toy beyond their reaching limits. Third, we intended to investigate the accuracy of parents' estimations of their child's behavior, considering some child's characteristics and parent's gender. Finally we sought to investigate potential predictors of children's maximum reachability and of parent's estimations of children's maximum reachability (i.e., morphologic variables, walking experience or swimming program experience).

## 6.3. Method

### *6.3.1. Participants*

A convenience sample of 76 parents (40 males and 36 females, ranging from 22.75 to 55.56 years, M=35.16 yr, SD=5.13 yr), and their children (N=76, 43 boys and 33 girls, ranging from 1.10 to 3.94 years, M=2.54 yr, SD=0.86 yr) participated in the study. Participants were recruited in a family health club in the Lisbon area, which offers aquatic programs for children starting from 3-months-old. Descriptive data of the children is presented in Table 6.1.

Table 6.1. Descriptive data of the children (N=76).

| Variable | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|
| Age (yrs) | 1.10 | 3.94 | 2.54 | 0.86 |
| Age at walking onset (yrs) | 0.75 | 1.33 | 1.00 | 0.12 |
| Walking experience (yrs) | 0.04 | 3.03 | 1.54 | 0.86 |
| Age at swimming program onset (yrs) | 0.19 | 3.86 | 1.27 | 1.02 |
| Swimming program experience (yrs) | 0.00 | 3.41 | 1.27 | 0.97 |
| Height (cm) | 72.50 | 111.00 | 89.74 | 8.35 |
| Arm span (cm) | 72.00 | 105.00 | 87.68 | 7.96 |
| Sitting height (cm) | 45.50 | 61.00 | 51.57 | 3.26 |
| Weight (Kg) | 10.00 | 24.00 | 14.20 | 2.60 |
| Maximum reachability (cm) | 15.00 | 55.00 | 35.00 | 8.45 |

*6.3.2. Apparatus*

A rubber duck was attached to a plastic structure that allowed the experimenter to move it away or closer to the swimming pool deck in 5 cm intervals (see Fig. 6.1).

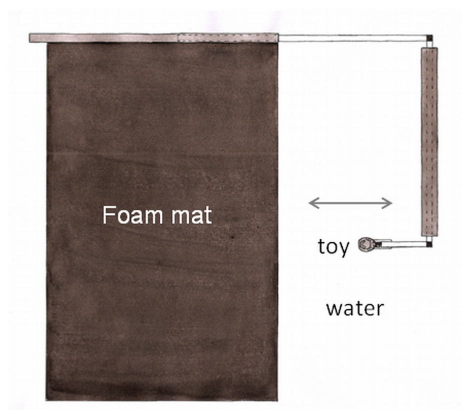


Fig. 6.1. Top view of the apparatus. A rubber duck attached to a plastic structure could be moved away or closer to the swimming pool deck, just above the water level.

*6.3.3. Procedures*

Prior to the experimental situation, approval from the Ethics Committee of the faculty and informed consent from the parents of the children were obtained. The parents filled in a questionnaire with descriptive data (e.g., birth dates of the parent and the child, child's age at walking onset). The child's stature, sitting height, arm span and weight were using standard techniques. Parents were asked to stand one step away from the pool border, facing the rubber duck, and to make judgments concerning the maximum horizontal reachability of their child. Maximum horizontal reachability was defined as the greatest distance at which the child could take the toy out of the water without jumping or falling into the swimming pool. The duck was initially positioned at the approximate distance of the child's arm and the parent would ask the experimenter to move it away or closer to the pool border until he/she considered that it was at his/her child's maximum reachability. Parents were told that the child would be placed standing on the border of the pool but that he/she would be allowed to choose his/her preferred position to try to get the toy out of the water. They were also told that an experimenter would be in the water to assist them if necessary. Parents were then asked what the expected behavior of their child would be when he/she could not reach the toy from the pool border (stay on the pool border or get in the swimming pool either by falling or jumping). The child was placed standing on the swimming pool border in front of the duck and was asked to get it out of the water without going into the pool. The duck was initially placed at the maximum horizontal reachability distance predicted by the parent and would be moved away from the pool border after each successful grasp, or closer to the pool border after each failure. For safety reasons the child was placed over a foam mat. All trials were recorded (25 Hz) using a video camera placed 2.30 m above the water level in a lateral position.

*6.3.4. Data Collection and Analysis*

The videotaped action modes that were adopted by each child were analyzed separately by two motor development experts (intra-observer reliability=1; inter-observer reliability=.99).

Accuracy of predicted behavior was obtained by comparing the parent's expected behavior for the child beyond maximum reachability distance (stay on the pool border or get in the swimming pool either by falling or jumping), with the actual behavior of the child. Two categories of accurate predictions and two categories of discrepant predictions were possible: i) the parent predicted that the child would fall in the water and the child fell in the water; ii) the parent predicted that the child would stay on deck and the child stayed on deck; iii) the parent predicted that the child would fall in the water and the child stayed on deck; iv) the parent predicted that the child would stay on deck and the child fell in the water.

Accuracy of reaching estimations was evaluated by absolute error (AE), which indicate the deviation in centimeters from accurate estimations (|estimation-actual reachability|), and error tendency (i.e., frequency of underestimations, accurate estimations, or overestimations). The estimations that differed less than ± 5 cm from the actual measure were considered accurate estimations (error tendency equals 0).

For the statistical analysis, independent samples T-tests were used to compare the performance of boys and girls, and the estimations of mothers and fathers. The Mann-Whitney test was employed to compare absolute error in underestimations and overestimations. Frequency distributions and chi-square test ($\chi^2$) were adopted to analyze error tendency, accuracy of predicted behavior, and action modes used for reaching the toy. A stepwise linear regression analysis was used to investigate predictors for maximum reachability and estimated maximum reachability.

**6.4. Results**

Four action modes for retrieving the toy out of the water were identified based on the child's position on the deck: sitting, squatting, crawling and ventral support (see Fig. 6.2).

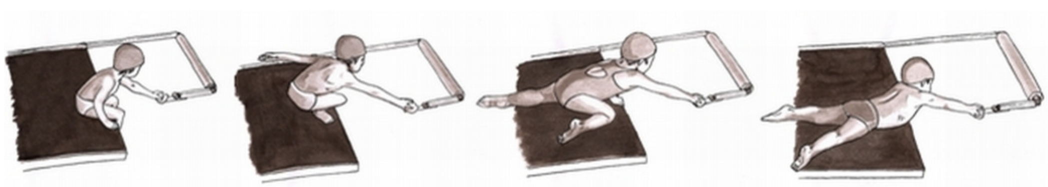

Fig. 6.2. Action modes used by the children to grasp the toy. From left to right: sitting, squatting, crawling and ventral support.

Most children (77.6%) chose the sitting posture to retrieve the toy out of the water. Other three action modes were used with lesser frequency, namely: squatting (9.2%), crawling (7.9%), and ventral support (5.3%).

When the toy was unreachable, 69.74% of the children fell or jumped in the water to grasp it. Most parents (78.95%) accurately predicted their child's behavior in this situation (see Fig. 6.3).

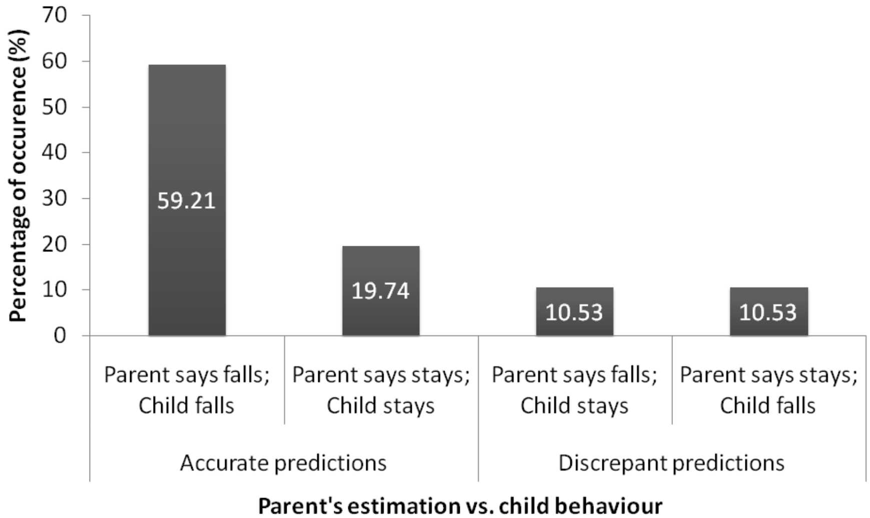


Fig. 6.3. Accuracy of predicted behavior after the child's maximum reachability.

Parent's accuracy of predicted behavior did not depend on the child's gender ($\chi^2(3)=1.578$, p=.664), or on the parent's gender ($\chi^2(3)=6.530$, p=.088).

Values of absolute error varied between 0 and 30 cm (M=8.49, SD=7.03), and were not significantly different for boys and girls (t(74)=-.325, p=.746), for fathers and mothers (t(74)=1.845, p=.069), or between underestimations (M=11.43, SD=6.56) and overestimations (M=9.17, SD=4.93) (U=310.00, p=.248).

Parents generally underestimated their children's reachability (55.3% underestimations, 21.1% accurate estimations, 23.7% overestimations). Error tendency was not significantly different for boys and girls ($\chi^2(2)=1.714$, p=.424), but it differed between fathers and mothers ($\chi^2(2)=6.219$, p=.045). Mothers had a greater number of accurate estimations (33.3%) than fathers (10.0%). Fathers underestimated and overestimated more than mothers (fathers: 62.5% of underestimations and 27.5% of overestimations; mothers: 47.2% of underestimations and 19.4% of overestimations).

A linear stepwise analysis in which the anthropometric variables, walking experience and a swimming program experience and were entered as independent variables, indicated as predictors of maximum reachability height and sitting height ($R^2=.469$; F=32.174, p<.001). For the prediction of estimated maximum reachability the same variables and the age of the observer were entered. Sitting height was the best predictor of estimated maximum reachability ($R^2=.209$; F=19.278, p<.001).

**6.5. Discussion**

The results of our study indicate that 70% of all children fell or jumped in the water beyond their maximum reachability distance. That was not surprising for most parents, and nearly 80 % of them accurately predicted what their child's behavior would be when the toy was no longer reachable. The major concern in terms of child safety is the discrepant judgment of 11% of parents who wrongly believed their child would stay on the deck when he/she could not reach the toy. Even though children were encouraged to retrieve the toy out of the water, and the environmental conditions were favorable for getting in the water (i.e., children in a bathing suit, warm water, experimenter in the water), nearly one third stayed on deck if the toy was beyond their maximal reachability. We believe that this percentage might be different (probably higher) in a different scenario (e.g., child dressed, cold water, no one around).

The environmental conditions might also have influenced the action mode chosen by the children to retrieve the toy out of the water. Most children (79 %) sat on the border of the pool to retrieve the toy. This seems to be the most comfortable action mode for this kind of tasks in children of this age. Most children sat with their feet in the water, but this could be different if they had shoes on, and probably some children would have tried different action modes. This is an interesting issue to address in future studies.

Most parents are generally cautious in predicting their child's maximum reachability in this swimming pool task. Around 55% underestimated their child's reachability, which contradicts the overestimation tendency verified by previous studies in horizontal (Fischer, 2003) and vertical reaching tasks (Cordovil & Barreiros, in press), when a first-person perspective (i.e., observer behind the model) is adopted. Some previous studies (Fischer, 2003; Rochat, 1995) have identified an underestimation tendency while judging other people's horizontal reachability, but when a third-person perspective (i.e., observer with a frontal view of the model) is adopted. Since that was not the case in the present study, we suspect that the underestimation bias might be a result of a protective tendency of parents that is more notorious in a risk environment.

Some parents (21.1%) accurately predicted their child's maximum reachability. However, there were also parents who had quite large values of absolute error (maximum= 30 cm), which indicate a lack of knowledge of their child's real action capabilities in this situation. This lack of knowledge did not depend on the error tendency, since absolute underestimation errors were not significantly different from absolute overestimation errors.

The child's gender did not influence absolute error or error tendency, indicating that the differential treatment for boys and girls reported by previous studies (Morrongiello & Dawber, 1998) was not verified, or did not result in differences in estimation accuracy in this study. Absolute errors were not significantly different between fathers and mothers, which is in accordance with previous studies that found no effects of observer's gender in the estimation accuracy of children's vertical reachability (Cordovil, Barreiros, & Fonseca, 2008). However, even though error magnitude was similar between genders, mothers had a greater frequency of accurate estimations (33.3%) than fathers (10%). Mothers have a traditional nurturing role, and even though fathers' involvement has been growing, they still spend significantly less time than mothers caring for their children (Lewis, 1997). We can speculate that mother's greater involvement with their children in younger ages might have led to a distinction in the way both genders estimated children's reachability.

Anthropometric characteristics, namely height and sitting height explained about 47% of the variability of maximum reachability. The small value of the coefficient of determination indicates that although reachability seems to be clearly constrained by one's body dimension (Carello, Grosofsky, Reichel, Solomon, & Turvey, 1989), it is also influenced by other factors in this specific task. Body dimensions have proven successful at identifying action limits in adults but not in very young children (Ulrich, Thelen, & Niles, 1990). Instead, experience (Adolph, 1997, 2000) seems to influence children's actions at younger ages. However, walking experience and swimming program experience did not significantly influence children's reaching limits in the task of retrieving a toy from the swimming pool. Parents' predictions of maximum reachability were also based on children's morphology, namely on sitting height, but only about 21% of the variability of predicted maximum reachability was explained by this variable. This indicates that, in this situation, parents probably rely on other variables to estimate their children's maximum reachability. Variables such as specific temperamental characteristics of the children (Schwebel & Barton, 2005) or even of the parents might influence parent's judgments of children's capabilities.

This study provides empirical evidence for the Centers for Disease Control and Prevention recommendation that the presence of toys in the swimming pool may encourage children to enter the pool area or lean over the pool and potentially fall in (CDC, 2004). When 1 to 4 year-olds were asked to reach a toy in a pool, they usually sat on the deck to reach it, and fell in or jumped in the water if the toy is unreachable. Other action modes were also observed. In addition, we verified that most parents were cautious in the swimming pool environment and underestimated their child's maximum reachability from the pool border. Mothers had a greater frequency of accurate estimations than fathers. Most parents also accurately predict their child's behavior when the toy is unreachable, but 10.53% of parents of children that fell or jumped in the water believed their child would stay on the deck, this discrepant situations represent a problem in terms of child safety.

The conclusions of this study evidenced the importance of adult supervision around water environments and underlined the need to remove toys from the pool and surrounding area immediately after use. Recreational water facilities should include devices to remove toys out of the water.  Since parental supervision is a key variable in drowning prevention, it is also important to remove obstacles that may limit visual information of the deck areas. The design of recreational swimming pools should afford easy and intuitive information of the water and surrounding areas. The most common action modes that children use for retrieving a toy out of the water are also described. Information about children behavior and parents' perception may be useful for educational purposes. This information can be used to focus and design interventions to improve caregiver's supervision in water environments in order to prevent drowning and near-drowning incidents with children.

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# 7. The efficacy of safety barriers for children: absolute efficacy, time to cross and action modes


### 7.1. Abstract

We examined the efficacy of safety barriers by testing their capabilities to prevent or delay crossing. Children between 19 and 75 months tried to climb different barriers selected for their age group, which represented the most common types of panel and horizontal bars barriers available on the market. Success or failure in crossing, time to cross, and crossing techniques were analyzed. Barrier characteristics' influenced its restraining efficacy. Children's success rate varied between 10% and 95.3%. None of the barriers assured a considerable protective delay. Three major action modes were identified: HOW (head over waist), HAW (head and waist), and HUW (head under waist). Generally children adopted the safer action mode (HOW) to cross most barriers. Younger children often adopted unstable action mode in barriers with crossable gaps. Although some standards might need to be re-evaluated, there are no childproof barriers. Barriers are time-delaying devices that cannot substitute supervision and education.


Key words: child safety, climbing, motor skills, protective devices, design.

### 7.2. Introduction

Falling from heights and drowning are two leading causes of death in children.

Drowning is the second leading cause of unintentional death in the EU (MacKay & Vincenten, 2007) and worldwide (Peden et al., 2008). Most victims are boys (Blum & Shield, 2000; Brenner, 2003; Peden et al., 2008; Peden & McGee, 2003; Vincenten, 2004) and the most vulnerable are children under 5 years of age (Peden et al., 2008; Peden & McGee, 2003; Vincenten, 2004). The drowning rate in low-income and middle-income countries (LMIC) is six times higher than in high-income countries. In LMIC most drowning deaths occur during daily activities in natural bodies of water and water collecting systems such as buckets, wells and cisterns. By contrast, in high-income countries (HIC) most childhood drowning occurs in recreational settings (Peden et al., 2008). Between 1 and 4 years of age children in HIC are most likely to drown in swimming pools (Brenner, 2003; Quan, Gore, Wentz, Allen, & Novack, 1989). For that reason, the development of early swimming competence (Brenner, Saluja, & Smith, 2003) and the access to swimming pools have been widely discussed (Blum & Shield, 2000; Brenner, 2003; Scott, 2003).

Falls also represent an important cause of injury and death. They are the leading cause of non-fatal child injury (Peden et al., 2008) but the distribution of fatal falls worldwide is not homogeneous. The rate of fatal falls is around six times higher in LMIC than in HIC, probably because there is an easier access to unprotected staircases, roofs, and unprotected rooftops in low development countries. These factors may create particular injury risks for falls (Peden et al., 2008).

Falls from heights (e.g., windows, balconies or stairs) are a major problem particularly in urban areas, with multiple-story buildings. Different studies report that these falls are more frequent in boys, younger than 5 years-old (Bulut, Koksal, Korkmaz, Turan, & Ozguc, 2006; Istre et al., 2003; Mayer, Meuli, Lips, & Frey, 2006; Peden et al., 2008; Vish, Powell, Wiltsek, & Sheehan, 2005), and tend to peak around summer months (AAP, 2001; Lallier, Bouchard, St-Vil, Dupont, & Tucci, 1999; Mayer et al., 2006; Pressley & Barlow, 2005; Vish et al., 2005).

Preventive strategies to reduce the incidence of drowning and falls from heights include environmental modifications, such as the installation of guards and barriers (on balconies, stairs, windows, terraces, galleries, swimming pools). These barriers are also used to prevent or delay children's access to dangerous places. Regulations and standards for safety barriers vary in different countries around the world; some are voluntary, others are mandatory (MacKay & Vincenten, 2007; Neto et al., 2008). Discrepancies in regulations and technical variability of solutions are a relevant component of this problem. Studies indicate that many times drowning and falls occur due to inadequate physical constraints, like inappropriately fenced swimming pools (Blum & Shield, 2000; Brenner, 2003), balconies with rails too spaced apart, or window sills too low (Istre et al., 2003). A correct installation and maintenance of safety barriers is also fundamental. When parents and caregivers perceive a safety deficit they frequently try to compensate it by adopting inappropriate measures such as covering barriers with inefficient malleable and poorly fixed nets, or placing solid protections that difficult rescue in case of fire. This type of solutions, which cause a risk situation not only for children but for the whole family, could be avoided through the implementation of an adequate building code (Neto et al., 2008).

Decisions about height and other characteristics of barriers have been based upon morphological descriptions of potential users, usually of a static nature. However, the perception of a complex built environment must be described as a dynamic process of movement since people discover architectural shapes and layouts as they move (Hölscher, Meilinger, Vrachliotis, Brösamle, & Knauff, 2006). Children, particularly, move in very creative ways and develop motor solutions for successfully crossing such devices. Gibson (Gibson, 1979) used the term affordance to describe the possibilities for action provided for the actor by the environment. To perceive an affordance, in Gibson's view, is to perceive how one can act when confronted with a particular set of environmental conditions. Children are continuously exploring their environment and as new motor solutions become available new affordances become potentially detected. Therefore a barrier designed for restraining a child might be perceived as a great challenge to climb, and an effective barrier may easily become not useful if a child discovers an alternative solution.

Research is required into children's ability to climb different types of restraining devices to argue for appropriate requirements in standards. To our knowledge, only four studies have focused in children's ability to climb safety barriers (Jaartsveld, Wolde, & van Aken, 1995; Nixon, Pearn, & Petrie, 1979; Rabinovich, Lerner, & Huey, 1994; Riley, Roys, & Cayless, 1998). The results of these studies indicate that the effective protection of the barriers is often very low, especially for older children, but it is more visible in higher barriers. Other design characteristics such as the flexibility of the barrier, the existence of support points to climb, or the existence of a retrofitted profile also seem to significantly influence the success rates in some barriers (Jaartsveld et al., 1995; Rabinovich et al., 1994). A very important finding is that when barriers do not offer total security, children who succeed in crossing do not need much time to do it. The mean time to overcome barriers was less than 30 seconds in most situations tested by different studies (Jaartsveld et al., 1995; Rabinovich et al., 1994; Riley et al., 1998).

In this study, we attempted to determine the efficacy of different types of restraining devices that represent market available solutions by testing their capabilities to prevent or delay crossing by children between 19 and 75 months.

## 7.3. Method

### *7.3.1. Participants*

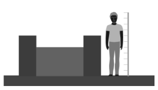
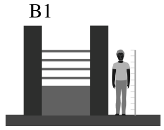
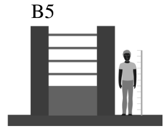
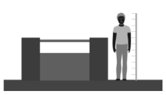
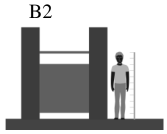
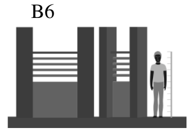
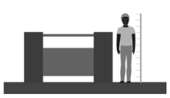
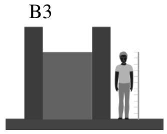
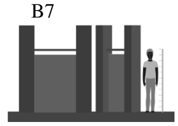
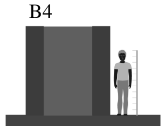
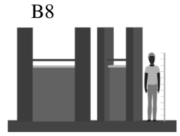
We used a convenience sample of children from 19 to 75 months (N=88), divided by two age groups: group A (30 children, 20 boys and 10 girls, from 19 to 35 months; M=28.02, SD=4.33 months); and group B (58 children, 28 boys and 30 girls, from 36 to 75 months; M=59.94, SD=9.29 months). The children had no behavioral disorders, motor problems or uncorrected sensorial deficits that would impair the performance of the task. Subjects belonged to two institutions and were engaged in regular Physical Education programs.

*7.3.2. Task*

Wearing comfortable clothes, children were asked to climb different types of barriers selected for their age group in a random sequence.

The experimental procedure is explained thoroughly in the ANEC technical report (Neto et al., 2008). A total of three barriers for group A and eight barriers for group B were tested, following recommendations and standards for panel and horizontal bars barriers (Table 7.1).

Table 7.1. Description of the barriers selected for the different age groups.

| Age group Children between 19 and 35 months-old | | Age group Children between 36 and 75 months-old | | | |
|---|---|---|---|---|---|
| Drawing | Short description | Drawing | Short description | Drawing | Short description |
| A1  | H = 50 cm | B1  | H = 110 cm<br>50 cm + 4 gaps of 11 cm + 4 bars of 4 cm | B5  | H = 138 cm<br>50 cm + 4 gaps of 18 cm + 4 bars of 4 cm |
| A2  | H = 67 cm<br>45 cm + 18 cm gap + 4 cm bar | B2  | H = 113 cm<br>11 cm gap + 80 cm + 18 cm gap + 4 cm bar | B6  | H = 110 cm<br>60 cm + 4 bars + backing rod (8.5 cm inwards; gap of 10.4 cm) |
| A3  | H = 78 cm<br>11 cm gap + 45 cm + 18 cm gap + 4 cm bar | B3  | H = 110 cm | B7  | H = 110 cm<br>100 cm + backing rod (8.5 cm inwards; gap of 10.7 cm) |
| | | B4  | H = 150 cm | B8  | H = 110 cm<br>100 cm + 2 backing rods (8.5 cm and 6.5 cm inwards; gaps of 8.5 cm and 9.19 cm) |

Notes: reference child 1.10 m tall; H - Total height of the barrier.

Instructions and encouragement were provided by a member of the experimental team or by the day care teacher. All children were filmed in their day care centre, with their teachers/educators nearby, in order to reduce the impact of a non-familiar environment. In group A several attractive toys were placed on the opposite side of the barrier in order to catch children's attention. Limit time to pass a barrier was 300 s. Children who couldn't cross the barrier after 300 s were allowed to go to the other side and play with the toys for a brief period in order to keep them motivated for the next barrier. For safety purposes, a gym mat was placed on the other side of the barriers and members of the experimental team stood nearby the child to provide protection if necessary.

In group A, all the 30 children tried to climb the 3 barriers. However, in group B, due to the greater number of barriers tested, the experimental situation was filmed in different days. As some children missed school in one of the testing days or presented some kind of restriction, the sample for each barrier was variable (between 38 and 52). All trials were video-taped, from behind, at a 25 Hz frequency. The video recordings were subsequently pasted into movie fragments for analysis. The following items were then considered: 1) success/failure in crossing the barrier, 2) time to cross the barrier (from the moment of the first contact with the barrier, before the climbing action, until contact with the floor on the other side, or until the last visible frame when contact was occluded by the barrier), and 3) passing technique (action modes adopted for crossing).

The influence of different barrier characteristics in time to cross was analysed through the comparison of pairs of barriers that share common characteristics (structure or height) differing in particular aspects (e.g., height, existence of footholds, retrofitted profile).

The action modes for crossing were classified following the criteria of action control and safety (Fig. 7.1). To determine which passing technique was adopted in each situation, two coders analyzed the movie fragments. Inter-observer reliability was 0.95.

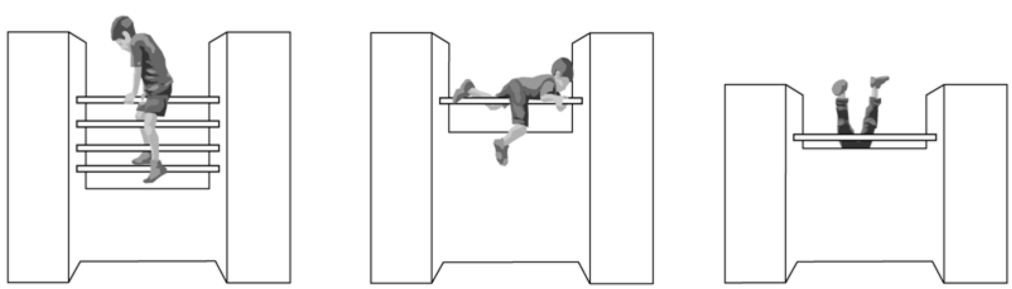


Fig. 7.1. Examples of 3 different action modes. Left - HOW (head over waist); Center - HAW (head and waist); Right - HUW (head under waist).

It was considered that when crossing a barrier with maximum control, children kept their vertical posture, with the head over the waist (HOW). Arms can move easily and balance is not greatly affected. The risk of falling is minimal. The second action mode is generally used when the level of difficulty of the barrier restrains the amount of options. In these situations, vertical balance is sacrificed in favor of a position that offers a greater contact between the body and the barrier. The barrier is crossed with the head and waist at the same level (HAW). This technique is more dangerous and guarantees less balance than the previous one. The third action mode is the most dangerous one since it is characterized by crossing with the head under the waist (HUW). This might represent a situation of a highly probable fall.

Sometimes the child exhibited more than one action mode to cross a barrier (e.g., started with HOW but when the second leg crossed the barrier shifted to a HAW mode). This and other possible mixed action types were registered and classified as “mixed techniques”.

Informed consent was obtained from the children’s parents. Caretakers and institutions were fully informed about the nature and purpose of the study. Approval from the Ethics Committee of the Faculty of Human Kinetics (Technical University of Lisbon, Portugal) was obtained.

*7.3.3. Statistical methods*

For the statistical analysis frequency distributions, measures of central tendency and chi-square test ($\chi 2$) were adopted. To analyze the time delaying capabilities of different barriers, comparisons were made using the Paired Samples Test or the Wilcoxon Signed Ranks Test in the cases in which the normality assumption was violated.

## 7.4. Results

*7.4.1. Crossing different barriers: children’s success rate*

The most obvious way to assess the efficacy of a barrier is to determine the percentage of effective crossings when trying to climb it. The children’s success rate is the inverse of the safety rate for a given barrier.

Results show that as ages increased, children became more skilful in this sort of tasks. In the younger group, the most difficult barrier could prevent crossing in 90% of the cases; in the less complex barrier 70% of all children exhibited one of the above mentioned crossing techniques. In the older group the more complex barrier allowed crossing for one third of the sample; however, the less complex barrier presented a success percentage of 95.3%, that is, almost everyone could pass it (Fig. 7.2).

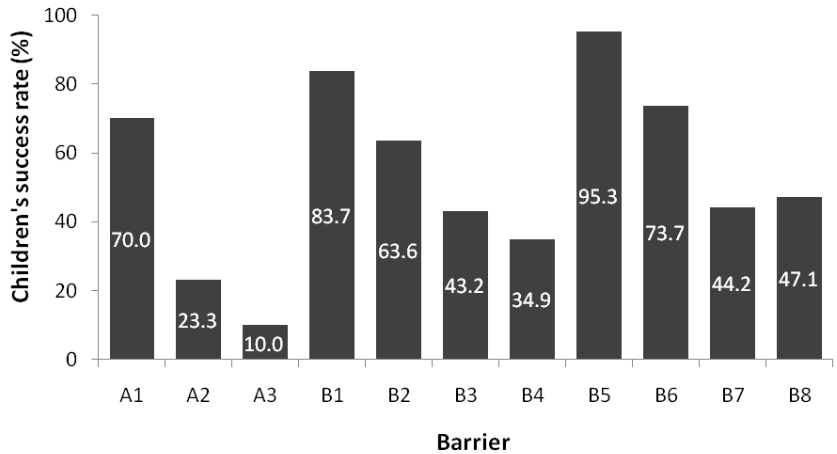



Fig. 7.2. Percentage of success in crossing different barriers.

To better understand the relationship between age and ability to cross barriers, we divided group B in 2 age groups: from 36 to 59 months-olds, and from 60 to 75 months-olds (Fig. 7.3).

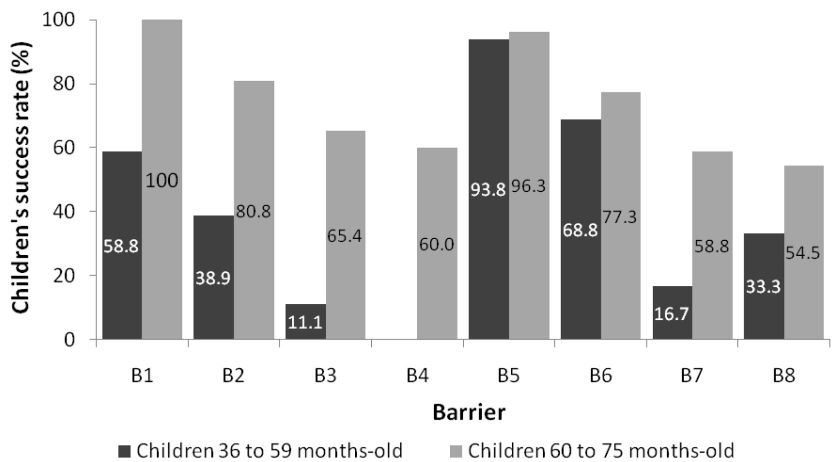



Fig. 7.3. Success rate in crossing different barriers by children 36 to 59 months-old and by children 60 to 75 months-old.

Group B results' indicate that none of the barriers seemed to be efficient enough to avoid most children over 60 months to cross it. The most difficult barrier was B4. This barrier seems to prevent crossing of the youngest children since no child under 60 months could cross it.

There were no differences in gender success rates found in our study except for barrier B7 ($\chi^2(1)=6.32$, $p=.025$) that was crossed mainly by boys.

*7.4.2. Crossing different barriers: measuring the time to cross*

From a child safety point of view it is important to investigate their delaying capacity, expressed by the time needed to cross each barrier. To meet this purpose, we analyzed the time the best climbers took to cross different barriers.

Each barrier was crossed by a different number of children (from 15 to 41 in group B). The most difficult barriers were crossed only by the most skilful climbers but the easiest barriers were crossed by good and bad climbers. To reduce the influence of different skill levels, and since in terms of safety we should consider the fastest children, we selected the 15 best climbers in each barrier to analyze the time it took to cross. This analysis was limited to group B since in group A the number of children that crossed some barriers was too reduced for testing. The results are shown in Table 7.2.

Table 7.2. Best climbers' time to cross for different barriers in Group B.

| Barrier | Time to cross of the 15 best climbers (in seconds) | | | |
|---|---|---|---|---|
| | Mean | SD | Min | Max |
| B1 | 6.60 | 1.30 | 4 | 9 |
| B2 | 10.93 | 3.39 | 5 | 17 |
| B3 | 9.13 | 3.94 | 3 | 14 |
| B4 | 14.33 | 7.39 | 6 | 36 |
| B5 | 7.60 | 1.84 | 4 | 10 |
| B6 | 10.80 | 4.28 | 4 | 18 |
| B7 | 6.87 | 2.95 | 3 | 12 |
| B8 | 8.80 | 3.59 | 2 | 12 |

The average time to cross for the best climbers varied between 6.6 s (B1) and 14.33 s (B4). Results indicated that mean time to cross was always lower than 15 seconds, and only three barriers (B2, B4 & B6) were able to offer a crossing time greater than 10 seconds. The most demanding barrier for the best climbers group (B4) was crossed in a maximum time of 36 seconds.

The analysis of all the episodes of successful crossing indicated that 231 (94.3%) occurred in less than 30 s, 13 (5.3%) took less than 60 s and only 1 (0.4%) episode lasted longer than one minute. These values clearly reflect the idea that there are no absolute safe barriers.

There were no significant differences in gender for time to cross most barriers. Only barriers A1 (Z=-2.05, p=.041) and B8 (Z=-2.17, p=.030) were more rapidly crossed by boys.

*7.4.3. Selected comparisons between barriers*

In order to determine the influence of different barrier characteristics in children's success rate and time to cross, seven pairs of barriers were compared (Table 7.3). We selected barriers that had similar general characteristics but differed in one specific characteristic, such as: height (measured from the floor to the top of the barrier), the existence of footholds (defined as elements outlined for the hand/ toe grip that provide support for the foot used for climbing a barrier), or the existence of a retrofitted profile (created by one or two backing rods on the upper part of the barrier). The comparisons between pairs of barriers indicated that some characteristics of the barriers influence children's success rate and time to cross.

Table 7.3. Influence of different barrier characteristics in children's success and time to cross.

| Barriers compared | | Characteristic compared | % of success in crossing | | | Time to cross (s) Mean | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1st B | 2nd B | | 1st B | 2nd B | $\chi^2$ | 1st B | 2nd B | Z | T |
| B3 | B4 | Height | 43.2 | 34.9 | 31.99*** | 10.60 | 14.33 | -2.35* | |
| B1 | B3 | Footholds | 83.7 | 43.2 | 6.62** | 8.42 | 11.74 | -2.12* | |
| B1 | B6 | Inwards rod (with footholds) | 83.7 | 73.7 | 4.31* | 10.77 | 15.45 | -2.99** | |
| B3 | B7 | Inwards rod (no footholds) | 43.2 | 44.2 | 19.67*** | 10.47 | 9.33 | -1.16 | |
| B3 | B8 | 2 Inwards rods (no footholds) | 43.2 | 47.2 | 24.57*** | 11.19 | 13.56 | -.483 | |
| B7 | B8 | Extra inwards rod (no footholds) | 44.2 | 47.2 | 29.86*** | 9.70 | 12.20 | | -2.56* |
| B6 | B7 | Footholds (with inwards rod) | 73.7 | 44.2 | 9.12** | 11.71 | 11.93 | | -.093 |

*p<.05 **p<.01 ***p<.001

The results indicated that increased height reduced the percentage of success in crossing ($\chi^2(1)$=31.99, p≤.001) and delayed time to cross (Z=-2.35, p=.019). On the other hand, footholds can transform a safer barrier into a dangerous one. Barriers with horizontal bars, which provided footholds, were easier to cross ($\chi^2(1)=6.62$, $p=.010$) and took less time to be crossed than panel barriers of the same height ($Z=-2.12$, $p=.034$). Footholds also make retrofitted barriers easier to climb ($\chi^2(1)=9.12$, $p=.003$).

In barriers with footholds, the existence of a cylinder rod rotating inwards reduced the crossing probability ($\chi^2(1)=4.31$, $p=.038$) and delayed it ($Z=-2.12$, $p=.034$). However, in solid panel barriers it facilitated climbing ($\chi^2(1)=19.67$, $p\leq.001$), as it offered additional grasping support. The percentage of success was even higher for barriers with 2 cylinder rotating rods in a different plane ($\chi^2(1)=24.57$, $p\leq.001$), probably for the same reason. Two inwards rods instead of one, increased children's success rate ($\chi^2(1)=29.86$, $p\leq.001$) but significantly delayed time to cross ($t(19)=-2.56$, $p=.019$).

*7.4.4. Action modes used to cross different barriers*

Most children crossed the barriers with their head over the waist (i.e., action mode HOW) (see Fig. 7.4). This seems to be the preferred mode when the barrier characteristics and the child's skill level allowed this kind of crossing. However, barriers with crossable gaps (e.g., barrier A2 and A3) seem to promote different kinds of crossing, since it is easier to pass between the gap with the head and waist at the same level (i.e., HAW) or with the head under the waist (HUW). These movements are dangerous crossing techniques because they limit the control of balance and movement, and may be associated with undesirable falls. The gaps of 18 cm were wide enough for younger children to pass without squeezing. Children in our study did not attempt to pass through the 11 cm gaps. The action mode HOW is much more frequent in the older group, indicating enhanced motor control and skill. Children in the younger group might still be testing other ways to cross barriers, even though they may look like unsafe behaviors.

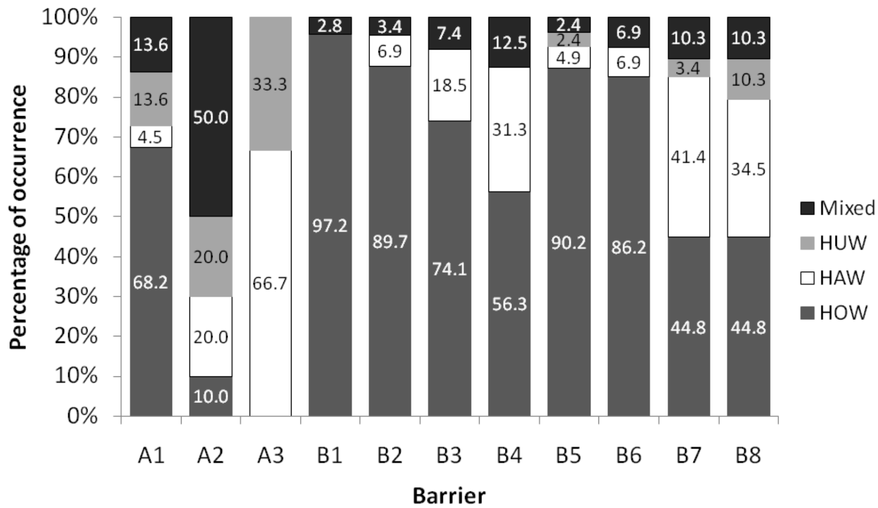



Fig. 7.4. Percentage of occurrence of the action modes used to cross different barriers.

**7.5. Discussion**

The findings of this study support previous investigations in children's ability to climb barriers (Jaartsveld et al., 1995; Nixon et al., 1979; Rabinovich et al., 1994; Riley et al., 1998) as they pointed to an easy and fast crossing of common barriers that are usually adopted as architectural solutions for restraining devices. The results also evidenced differences among various types of barriers.

As age increases, children become more skilful in climbing barriers and by the age of 5 most children seem to be able to climb any kind of the most common barriers available on the market. The most efficient barrier in our study was the 1.50 m solid panel. This barrier was crossed by 34.9% of the children in group B and represents the most demanding standard worldwide for swimming pools protection.

A greater height and the non-existence of footholds enhanced barriers restraining capacity. The influence of retrofitted profiles seems to be dependent on other barrier characteristics. In this study, retrofitted profiles increased the restraining capacity of barriers with footholds but decreased it in solid panel barriers, probably because they offer extra grasping points.

Barriers may create temporary negative affordances in the environment. However, when children are able to cross barriers they can do it very rapidly. In this study, 94.3% of all the successful crossings occurred in less than 30 s and only one crossing (0.4%) lasted more than 1 minute. These data reinforce the need for an appropriate adult supervision around risky environments. Parents and caregivers must be aware of that, and strategies to control and reinforce supervision must be developed. Lapses in appropriate supervision have been identified as a factor across a range of childhood injuries (Morrongiello, 2005; Saluja et al., 2004).

In most barriers, we found no significant differences between gender for the success rate or time to cross. This indicated that the prevalence of injuries in boys was not related to differences in physical ability but might be related to other factors, such as risk perception, different socialization of gender roles, and propensity for risk-taking behaviors (Hillier & Morrongiello, 1998; Little, 2006; Morrongiello & Dawber, 1998; 1999; 2000; Morrongiello, Midgett, & Stanton, 2000; Morrongiello, Ondejko, & Littlejohn, 2004; Morrongiello & Rennie, 1998; Schwebel & Barton, 2005).

Generally children adopted the safer action mode (HOW) to cross most barriers. However, younger children tended to adopt more often more unstable solutions mainly in barriers with crossable gaps (e.g., barrier A2 and A3). These barriers are in accordance with some international regulations (e.g., "NF P01-012: Dimensions des garde-corps - Règles de sécurité relatives aux dimensions des garde-corps et rampes d'escalier," 1988) that state the dimension of 0.18 m, if the gap is ≥ 0.45 m above the floor. Many balconies have protections that follow this standard but our results recommend its re-examination. In this study there were no occurrences of entrapment of the child in the barrier or of snagging of their clothing on portions of the barriers, probably because children didn’t try to pass through the 11 cm gaps. The space between bars is an important issue, which requires further investigation with younger children, because gaps shouldn’t allow children to pass trough and should not have dimensions that might cause children’s entrapment. In some situations the gap is wide enough for the child’s chest to pass through but not wide enough for the head, causing strangulation if the child’s body slides down and the head is entrapped (i.e., head entrapment by feet-first action). Head entrapment might also occur by head-first, this generally occurs when children place their heads through an opening in one orientation, turn their heads to a different orientation, then are unable to withdraw from the opening.

Some studies indicate that the characteristics of the environment and the perceptions of children's accident risk shape caregivers behaviors (Chen et al., 2007; Gärling & Gärling, 1990; Miller, Shim, & Holden, 1998). Parents' perceptions, attitudes and behaviors towards child safety were investigated by Vincenten, Sector, Rogmans, and Bouter (2005). Most parents indicated that the major difficulty to protect their children from accidental injury is that they are not able to watch their children constantly. Lack of awareness or knowledge about the causes of accidents was the second response. Therefore, permissive standards are major problems since inappropriately designed barriers might not be easily identified by parents and supervisors, who might be mislead to trust in a non-existent protection effect. Conversely, when a lack of safety is identified, parents and supervisors must seek advice to install and secure safety barriers properly, in order to avoid the use of unsafe solutions, which maintain or even increase the risk situation, causing a false sense of security.

Parental perceptions about children's injury risk are often unrealistic (Michalsen, 2003; Moran & Stanley, 2006a; Spinks et al., 2008). Moran and Stanley (2006) showed that parents, especially those whose children were enrolled in swimming lessons, had an overly optimistic view of the protective role of swimming ability in toddler drowning prevention. Approximately one-third of swim school parents believed that it was better to develop toddler swimming ability rather than rely on adult supervision. In a second study (Moran & Stanley, 2006b), the authors demonstrated that an education program, which addressed parental misconceptions, improved parental awareness of toddler water safety.

Pool fencing and window and balcony guards have been referred as effective strategies to reduce drowning and fall injuries and deaths (Vincenten, 2005; Vincenten & Michalsen, 2002). However, parents should not totally rely on barriers to prevent access to dangerous places or falling injuries, since physical barriers are just a part of a trilogy that also involves education and supervision. Education is a valuable component that should be incorporated into most injury prevention strategies. As biological entities, children do not have full awareness of right and wrong, or appropriate/inappropriate. The perception and categorization of things and behaviors as good and bad requires an adequate and continuous set of demonstrations, instructions, and knowledge. That is part of the educational process, and it cannot be expected to develop spontaneously. Education might also be a useful tool to encourage the use of passive measures, such as applying safety barriers near risk environments. However, there is no evidence to show that education on its own can reduce injuries (Peden et al., 2008). Adequate supervision is the third element. Our data suggests that even a little moment can offer the opportunity to cross a barrier. Parents and caregivers must be aware of that, and strategies to control and reinforce supervision must be developed. A barrier may be just a time delaying device that can give the opportunity for adult intervention; not an absolute preventive tool.

It is important to note that in the present research we did not address barriers overcome by children in real-world settings. Strictly for methodological reasons, children were encouraged to pass the barriers under controlled and assisted conditions, and they were asked to do something they know they should not. In fact, that is the only way to test the overcoming resilience of a barrier. The results of the study are a natural outcome of the method developed. The findings reported must take this methodological strategy into consideration.

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# 8. Crossing safety barriers: influence of children's morphological and functional variables


## 8.1. Abstract

The influence of morphological and functional variables on children's success rate and time to cross four protection barriers was examined. Thirty-three children, aged between 3.6 and 6.2 years (M=5.08, SD=0.80) tried to climb four barriers. Morphological and functional variables of the children, which were expected to influence climbing or passing through skills, were collected. The influence of these variables in success in crossing and in time to cross was analyzed. No barrier offered a total restraining efficacy for children of the studied age group. The horizontal bars barrier was crossed by 97% of the children. In the group of children that succeeded in crossing the four barriers, mean time to cross the most difficult barrier was 15 seconds. Age, strength and morphological variables connected to linear expressions of growth were determinant for success in crossing barriers. The influence of anthropometric variables in time to cross was dependent upon the characteristics of the barrier, but anthropometric characteristics were strong predictors of time to cross most barriers. As children grow older and stronger, with bigger stature, bigger arms and legs, and a bigger maximum vertical reaching height, their ability to cross barriers increases while the time to do that decreases.


Keywords: child safety; climbing; safety barriers; anthropometric measurements; falls; drowning.

## 8.2. Introduction

Falling from heights and drowning are two leading causes of injury and death in children (Peden et al., 2008). Risk factors that are associated with injuries in children include environmental and family related variables, but also individual characteristics of children, namely age, gender, and behavior (Bishai et al., 2008). The distribution of falls and drowning worldwide is not homogeneous, being around six times higher in low- and middle-income countries (LMIC) than in high-income countries (HIC) (Hyder et al., 2008; Hyder, Sugerman, Ameratunga, & Callaghan, 2007; Peden et al., 2008; Peden & McGee, 2003). Most victims from falls and drowning are boys under 5 years of age (Bulut, Koksal, Korkmaz, Turan, & Ozguc, 2006; Istre et al., 2003; Mayer, Meuli, Lips, & Frey, 2006; Peden et al., 2008; Vish, Powell, Wiltsek, & Sheehan, 2005).

A common solution to reduce the incidence of drowning and falls from heights, especially in HIC, is to use environmental modifications, such as guards or barriers, in balconies, stairs, windows, terraces, galleries, and swimming pools. However, sometimes, the barriers are not effective enough, which might be due either to the nature of the barrier or to the behavior of the child. Some injuries may involve the ability of children to overpass protection barriers, as it happens in the case of falling from balconies or drowning in swimming pools. In this case, the morphological characteristics of children may also play a relevant role in the design of safe environments.

The great variability of regulations, standards, and technical solutions for safety barriers in different countries around the world (MacKay & Vincenten, 2007; Neto et al., 2008) is a part of this problem. Inappropriately protected environments are a cause of many child injuries (Blum & Shield, 2000; Brenner, 2003; Istre et al., 2003).

Some studies have focused in children's ability to climb safety barriers indicating that the effective protection of the barriers is often very low, especially for older children (Cordovil, Barreiros, Vieira, & Neto, 2009; Jaartsveld, Wolde, & van Aken, 1995; Nixon, Pearn, & Petrie, 1979; Rabinovich, Lerner, & Huey, 1994; Riley, Roys, & Cayless, 1998). The time to cross a barrier also depends on the structure of the barrier. Some studies indicate that when barriers do not offer total security, children who succeed in crossing them can do it in less than 30 seconds (Cordovil et al., 2009; Jaartsveld et al., 1995; Rabinovich et al., 1994; Riley et al., 1998).

Children's morphology has often been referred as an influential variable in the development of motor competence and skill. The effect of body dimensions, body proportions, and gender differences on children's motor performance has been widely explored. The literature suggests that 10% to 25% of children's motor skill performance may be explained by morphological characteristics (Gabbard, 1992; Payne & Isaacs, 1995), but the effects of specific body dimensions may well be task specific.

Historically, a first set of observations (Norval, 1947; Shirley, 1931) emphasized the role of lower limb linear dimensions and muscle mass in the onset of walking. Later, the relationship between overweight and obesity, and motor development between 6 and 18 months of age was demonstrated (1982). The mobility of a child in a given environment is partially dependent of body dimensions and related functional variables. Other studies suggested that the correlation between body mass and motor development was extensive to older children (Graf et al., 2004), and that variables such as stature, biacromial breadth, and leg length were correlated with fundamental skills performance, balance, and strength during childhood (Benefice & Malina, 1996; Branta, Morrison, Kelly, Haubenstricker, & Seefeldt, 2007).

The security offered by protection barriers has possibly been conceived on the basis of children's height, but the available literature does not offer substantial morphological grounded support for barrier's dimensions. Additionally, the legal standards exhibit a remarkable variation among different countries (MacKay & Vincenten, 2007; Neto et al., 2008).

Although previous research on the efficacy of protection barriers has underlined the role of individual differences, the role of morphological characteristics has not been thoroughly analyzed. In this study, we will attempt to determine the influence of several morphological and functional variables on the success rate and time to cross four protection barriers. We hypothesized that the children with longer linear measures and/or with greater strength: i) would cross more safety barriers than smaller and weaker children; ii) would cross safety barriers faster than smaller and weaker children.

**8.3. Method**

*8.3.1. Participants*

We assessed 33 children (17 boys and 16 girls) aged between 3.6 and 6.2 years. The children had no behavioral disorders, motor problems or uncorrected sensorial deficits that would impair the performance of the task. Descriptive statistics of the participants' anthropometric variables are presented in Table 8.1.

Table 8.1. Descriptive statistics of the participants' anthropometric variables.

| Variable | Minimum | Maximum | M | SD |
|---|---|---|---|---|
| Age (years) | 3.55 | 6.23 | 5.08 | 0.80 |
| Stature (cm) | 93.40 | 130.50 | 111.25 | 7.81 |
| BMI (kg/m$^2$) | 12.81 | 20.03 | 15.95 | 1.43 |
| ADL (cm) | 39.80 | 55.90 | 47.30 | 3.52 |
| TH (cm) | 45.70 | 65.00 | 55.05 | 4.74 |
| APCB (cm) | 11.40 | 13.70 | 12.73 | 0.65 |
| MVRH (cm) | 118.00 | 161.80 | 138.97 | 9.99 |
| Strength (kg) | 3.00 | 19.25 | 9.03 | 3.19 |
| RS (kg/kg) | 0.23 | 0.63 | 0.45 | 0.11 |

Notes: BMI – Body Mass Index; ADL – Acromiale-Dactylion Length; TH – Trochanterion Height; APCB - Anterior-Posterior Chest Breadth; MVRH – Maximum Vertical Reaching Height; RS-Relative Strength.

*8.3.2. Anthropometric variables*

The morphological variables were selected for their expected influence in this kind of skills.

A first group included variables that helped to reach objects put at a high level and/or climb barriers, namely: maximum vertical reaching height (MVRH), acromiale-dactylion length (ADL) (i.e., upper limb length), trochanterion height (TH) (i.e., lower limb length) and stature. We also selected a variable related to the capability of passing between two obstacles, the anterior-posterior chest breadth (APCB). Finally, we selected variables related to the ability of grasping objects and moving the body over the obstacles, specifically: strength (handgrip), relative strength (handgrip/weight) and body mass index (weight/heigth$^2$). The anthropometric measures were obtained according to ISAK (Marfell-Jones, Olds, Stewart, & Carter, 2006) with the exceptions of the maximum vertical reaching height. To measure MVRH, the child assumed a standing position, bare-footed facing the anthropometer as close as possible and raised his dominant upper limb extended with his hand opened with the fingers together, pushing up, as far as possible, without raising the heels from the floor.

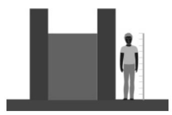
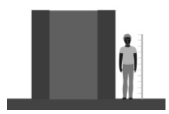
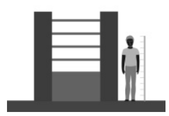
All the anthropometric variables were obtained before the experimental task by an accredited level 3 ISAK anthropometrist.

*8.3.3. Task*

Wearing comfortable clothes, children were asked to climb different types of barriers selected for their age group in a random sequence.

Four barriers were tested, following recommendations and standards for panel and horizontal bars barriers (Table 8.2).

Table 8.2. Description of the barriers selected.

| Barrier | Drawing | Short description |
|---|---|---|
| A |  | H = 110 cm |
| B |  | H = 150 cm |
| C |  | H = 138 cm<br>50 cm + 4 gaps of 18 cm + 4 bars of 4 cm |
| D |  | H = 110 cm<br>100 cm + backing rod (8.5 cm inwards; gap of 10.7 cm) |

Notes: reference child 1.10 m tall; H - Total height of the barrier.

All children were filmed in their day care centre, with their teachers/educators nearby, in order to reduce the impact of a non-familiar environment. Instructions and encouragement were provided by a member of the experimental team or by the day care teacher. Limit time to pass a barrier was 300 s. For safety purposes, a gym mat was placed on the other side of the barriers. A physical education teacher stood nearby the child to provide protection if necessary.

All trials were video-taped, from behind (25 Hz). The video recordings were subsequently pasted into movie fragments for analysis. The following items were then considered: 1) success/failure in crossing the barrier and 2) time to cross the barrier, in seconds (from the moment of the first contact with the barrier, before the climbing action, until contact with the floor on the other side, or until the last visible frame when contact was occluded by the barrier).

*8.3.4. Statistical methods*

For the statistical analysis frequency distributions, measures of central tendency and chi-square test ($\chi^2$) were adopted. Analysis of variance (ANOVA) with Boferroni post hoc procedures were employed to compare the time delaying capabilities of different barriers. The Huynh-Feldt correction was used in cases of violations of sphericity. Independent samples T-tests were used to compare the morphological characteristics in children that failed versus children that succeed crossing each barrier. To analyze the relationship between children's variables and time to cross different barriers, Pearson correlations and linear stepwise regressions, were adopted.

## 8.4. Results

*8.4.1. Crossing different barriers: children's success rate*

To assess the efficacy of a barrier we determined the percentage of effective crossings when trying to climb it. The children's success rate is the inverse of the safety rate for a given barrier (Cordovil et al., 2009). There were no significant differences in the success rate of boys and girls for any of the barriers. The success rate was influenced by the type of barrier ($\chi^2(3)=12.00$, $p=.007$). Results show that barrier C was quite inefficient for this age group and no barrier offered a total restraining efficacy (see Fig. 8.1).

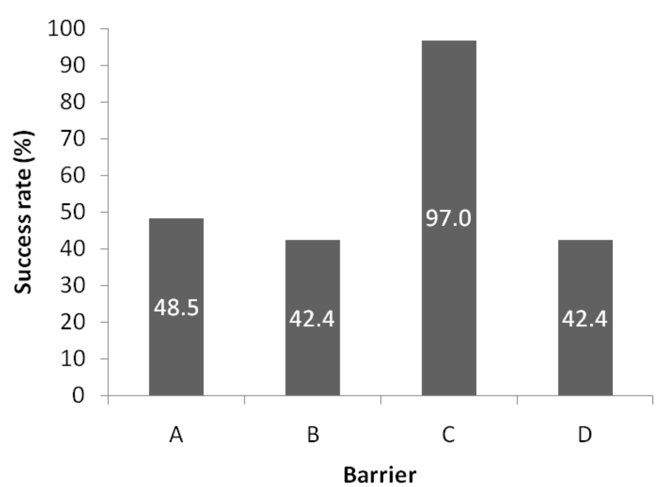



Fig. 8.1. Percentage of success in crossing different barriers.

### *8.4.2. Crossing different barriers: measuring the time to cross*

Twelve children (36.36 %) succeeded in crossing all the barriers. Descriptive statistics concerning the delaying capacity of each barrier are presented in Table 8.3.

Table 8.3. Descriptive statistics of time (s) to cross each barrier by the 12 children who succeeded in crossing the four barriers.

| Barrier | Minimum | Maximum | M | SD |
|---|---|---|---|---|
| A | 3 | 24 | 11.17 | 5.97 |
| B | 7 | 36 | 15.00 | 7.90 |
| C | 4 | 13 | 8.58 | 2.75 |
| D | 3 | 12 | 6.83 | 3.13 |

Results indicated that mean time to cross was always inferior to 15 seconds and some children can cross some barriers in no longer than 3 seconds. Analysis of variance revealed a significant effect of Barrier on children's time to cross ($F(2,20)=8.179$, $p=.003$, $\eta^2_p=.426$). Post hoc testing revealed that time to cross barrier B was significantly greater than time to cross barrier D ($p=.031$). There were no gender differences in time to cross the barriers.

### *8.4.3. Influence of morphological variables*

#### *8.4.3.1. Morphological variables and success in crossing different barriers.*

The comparison between the morphological characteristics of the group of children that crossed each barrier versus the group that couldn't cross was only performed when both groups had at least 30% of the total sample. This criterion excluded barrier C from this analysis. Data relative to the comparison of different morphological characteristics in children that failed versus children that succeeded in the action of crossing each barrier are shown in Table 8.4.

Table 8.4. Descriptive statistics and independent samples T tests for the variables of children who failed and succeeded in crossing barriers A, B and D.

| | | Barrier | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | A | | | B | | | D | | |
| Variable | Group | N | M (SD) | T (DF=31) | N | M (SD) | T (DF=31) | N | M (SD) | T (DF=31) |
| Age | NS | 17 | 4.65 (0.71) | 3.777**a) | 19 | 4.60 (0.70) | 6.193*** | 19 | 4.69 (0.77) | 4.236***b) |
| (Years) | S | 16 | 5.54 (0.64) | | 14 | 5.74 (0.34) | | 14 | 5.62 (0.47) | |
| Stature | NS | 17 | 107.56 (6.02) | 3.166** | 19 | 107.15 (6.30) | 4.402*** | 19 | 107.92 (6.67) | 3.254** |
| (cm) | S | 16 | 115.16 (7.72) | | 14 | 116.80 (6.12) | | 14 | 115.76 (7.09) | |
| BMI | NS | 17 | 15.56 (1.43) | 1.679 | 19 | 15.58 (1.36) | 1.795 | 19 | 15.65 (1.40) | 1.439 |
| ($kg/m^2$) | S | 16 | 16.37 (1.35) | | 14 | 16.45 (1.41) | | 14 | 16.36 (1.41) | |
| ADL | NS | 17 | 45.52 (2.81) | 3.466** | 19 | 45.46 (2.95) | 4.396*** | 19 | 45.74 (3.02) | 3.407** |
| (cm) | S | 16 | 49.19 (3.27) | | 14 | 49.79 (2.62) | | 14 | 49.41 (3.11) | |
| TH | NS | 17 | 52.86 (3.77) | 3.077** | 19 | 52.53 (3.92) | 4.497*** | 19 | 52.92 (4.11) | 3.502** |
| (cm) | S | 16 | 57.38 (4.64) | | 14 | 58.46 (3.48) | | 14 | 57.94 (4.03) | |
| APCB | NS | 17 | 12.57 (0.70) | 1.493 | 19 | 12.56 (0.67) | 1.855 | 19 | 12.56 (0.67) | 1.792 |
| (cm) | S | 16 | 12.90 (0.55) | | 14 | 12.96 (0.55) | | 14 | 12.96 (0.55) | |
| MVRH | NS | 17 | 133.91 (8.20) | 3.484** | 19 | 133.59 (8.51) | 4.592*** | 19 | 134.34 (8.87) | 3.646** |
| (cm) | S | 16 | 144.35 (9.03) | | 14 | 146.26 (6.78) | | 14 | 145.25 (7.94) | |
| Strength | NS | 17 | 7.26 (2.22) | 3.955*** | 19 | 7.41 (2.50) | 4.191*** | 19 | 7.80 (2.63) | 2.845** |
| (kg) | S | 16 | 10.91 (3.03) | | 14 | 11.23 (2.71) | | 14 | 10.70 (3.21) | |
| RS | NS | 17 | 0.40 (0.10) | 2.896** | 19 | 0.41 (0.11) | 2.641* | 19 | 0.42 (0.11) | 1.716 |
| (kg/kg) | S | 16 | 0.50 (0.09) | | 14 | 0.50 (0.08) | | 14 | 0.48 (0.10) | |

Notes: a) DF=28; b) DF=30; NS – Group that did not succeed in crossing the barrier; S – Group that succeed crossing the barrier; BMI – Body Mass Index; ADL - Acromiale-Dactylion Length; TH - Trochanterion Height; APCB - Anterior-Posterior Chest Breadth; MVRH - Maximum Vertical Reaching Height; RS – Relative Strength.

*p<0.05;**p<0.01; ***p<0.001.

Age, strength and morphological variables connected to linear expressions of growth seem to be determinant for crossing barriers. Older and stronger children, with bigger arms and legs, and bigger maximum vertical reaching heights, had a greater success rate in crossing all the barriers.

*8.4.3.2. Morphological variables and time to cross different barriers.*

Some individual characteristics of the children, such as age, body dimensions and strength, influence their ability to climb. It would be expected that older, taller and stronger children took less time to cross most barriers than younger, shorter and weaker children. In order to verify this assumption, we analyzed the correlations between those characteristics and time to cross different barriers (Table 8.5).

Table 8.5. Values of Pearson correlation between time to cross each barrier and the morphological variables of children who succeeded in crossing.

| | Barrier | | | |
|---|---|---|---|---|
| | A | B | C | D |
| Variable | r | r | r | r |
| Age (years) | -0.483 | 0.375 | -0.596*** | -0.511 |
| Stature (cm) | -0.609* | 0.199 | -0.576** | -0.571* |
| BMI ($kg/m^2$) | -0.203 | 0.079 | -0.128 | -0.201 |
| ADL (cm) | -0.616* | 0.040 | -0.518** | -0.613* |
| TH (cm) | -0.550* | 0.250 | -0.550** | -0.512 |
| APCB (cm) | -0.320 | 0.094 | 0.818 | -0.151 |
| MVRH (cm) | -0.673** | 0.083 | -0.582*** | -0.591* |
| Strength (kg) | -0.573* | 0.120 | -0.538** | -0.688** |
| RS (kg/kg) | -0.439 | 0.003 | -0.513** | -0.649* |

*p<0.05;**p<0.01; ***p<0.001.

Body mass index and APCB were not related with time to cross any of the barriers in this study. The influence of anthropometric variables is clearly dependent upon the characteristics of the barrier. In the barrier B none of the anthropomentric variables was correlated with time to cross, whilst in the barrier C most morphological variables were negatively correlated with time to cross.

Concerning barriers A and D, the only variables not significantly associated with time to cross, besides BMI and APCB, were age and relative strength in the Barrier A, and age and throchanterion height in barrier D.

A linear stepwise analysis indicated as predictors of the time to cross the following variables: MVRH and ADL ($R^2$=.622; F=10.681, p=.002) for barrier A; Age ($R^2$=.355; F=16.521, p<.001) for barrier C and strength ($R^2$=.474; F=10.799, p=.007) for barrier D.

**8.5. Discussion**

The primary intent of the present study was to determine the influence of several morphological and functional variables on the success rate and time to cross of four protection barriers, which were selected following recommendations and standards for panel and horizontal bars barriers.

Children were encouraged to pass the barriers, under controlled and assisted conditions, in order to evaluate the efficacy of the barriers and to understand the role of morphological variables and the time needed to do it. This is the usual methodological procedure in this type of studies (Cordovil et al., 2009; Jaartsveld et al., 1995; Nixon et al., 1979; Rabinovich et al., 1994; Riley et al., 1998) since that is the only safe way to test children's climbing capabilities and barriers efficacy.

The influence of children's morphological characteristics in the ability to cross safety barriers was notorious, confirming our initial hypotheses. As children grow older and stronger, with bigger stature, bigger arms and legs, and a bigger maximum vertical reaching height, their ability to cross barriers increases while the time to do that decreases. Body mass index (BMI) and anterior-posterior chest breadth (APCB) were the only variables that did not seem to influence the ability to transpose any of the studied barriers. In our study, the average BMI of children is within the normal parameters for age and sex both in respect of the NHANES III (Frisancho, 2008) and Cole (Cole, Bellizzi, Flegal, & Dietz, 2000; Cole, Flegal, Nicholls, & Jackson, 2007) cut off points, therefore the presence of extreme cases could not be analyzed. APBC is a variable related to the capability of passing between two obstacles. The gaps under evaluation were large enough for every child to pass easily or too narrow and no child passed through it.

Anthropometric characteristics were strong predictors of time to cross some barriers. In barrier A, MVRH and ADL accounted for 62% of the differences in time to cross, and in barrier D strength accounted for 47% of those differences. Age was the strongest predictor of time to cross only in barrier C, accounting for 36% of its differences.

We can conclude that morphological variables, particularly those connected to linear expressions of growth, play a very important role in these types of tasks. The arm length and strength are also highly related with time to cross. Strength was the major predictor for time to cross barrier D, which emphasizes the inadequacy of simple static body dimensions. No variable seemed to be determinant for the time needed to cross barrier B. One possible explanation is that B was the most difficult barrier to cross, and the few children who could cross it were tall and strong enough to jump and hold on to the top (1,50 m), pull themselves up using their arms and throwing one leg over the edge of the horizontal support to pass to the other side. Anthropometric characteristics of these children were probably very similar masking their effects on time to cross it. An alternative explanation is that the difficulty level of barrier B required sophisticated motor coordination but not specific anthropometric characteristics.

In accordance with previous studies (Cordovil et al., 2009), we confirmed that none of the tested barriers was absolutely safe. Children's success rates varied between 42.4% and 97%, clearly indicating that horizontal bars barriers are not appropriate to avoid the access of children to risk environments.

The findings relative to time to cross also support previous investigations (Cordovil et al., 2009; Jaartsveld et al., 1995; Nixon et al., 1979; Rabinovich et al., 1994; Riley et al., 1998) as they pointed to a fast crossing of most common barriers. In the group of children that succeeded in crossing the four barriers, the mean time to cross the most difficult barrier was 15 seconds, and maximum observed time was 36 seconds. This barrier, a 1.50 m solid panel that represents the most demanding standard worldwide for swimming pools protection, had a delaying capability significantly greater than the retrofitted profile (i.e., backing rod) barriers. In good climbers, the backing rod was associated with a shorter time to cross the barrier, probably due to the additional grasping point that it provided. None of the tested barriers could assure a significantly protective delay. Best climbers can cross a difficult barrier in just a few seconds. There are some indications that a better motor ability is associated with an increase in the incidence of injuries in primary school children, probably due to a greater exposure to risk situations (Gofin, Donchin, & Schulrof, 2004). These data emphasize the need for an appropriate adult supervision around risky environments.

No gender differences were observed, as in previous studies with these type of tasks (Cordovil et al., 2009), indicating that prevalence of injuries in boys was not related to differences in physical ability but might be related to other factors, like engagement in risk-taking activities (Eaton & Yu, 1989; Morrongiello & Dawber, 1998; Morrongiello, Ondejko, & Littlejohn, 2004; Morrongiello & Rennie, 1998), intensity of play (Eaton & Yu, 1989), socialization (Morrongiello & Dawber, 1999; Morrongiello & Dawber, 2000), and risk perception (Hillier & Morrongiello, 1998).

Our results show that children can cross barriers in few seconds. Parents and caregivers must be aware of that, and strategies to control and reinforce supervision must be developed. Previous research indicates that parent education both through parent education programs and through informal media outlets (e.g., parenting magazines) might be effective in improving parental awareness of children's injury risk (Gaines & Schwebel, 2009; Moran & Stanley, 2006). Education might also be a vehicle to guarantee the enforcement of proven prevention measures and child friendly legislation, and a strategy to encourage the use of passive measures (e.g., environmental modifications). Pool fencing and balcony guards are environmental modifications that afford an effective passive protection to reduce drowning and fall injuries and deaths (Peden et al., 2008; Vincenten, 2005; Vincenten & Michalsen, 2002). However, as we have seen, this engineering prevention strategy should consider children's morphological and functional characteristics, and should be complemented by education and supervision. Safety barriers are not absolutely efficient preventive tools; they are just time delaying devices that can give the opportunity for adult intervention.

In conclusion, our study illustrates the importance of adult supervision around risk environments. The results indicate that horizontal bar barriers are not efficient to restrain children's access to dangerous places. However, in some countries the use of this type of barriers in balconies is frequent due to the inexistence of legislation or mandatory building codes that enforce the use of more efficient safety barriers. Safety barriers are more efficient in preventing younger, smaller and weaker children's access to risk environments. The time that children take to cross some safety barriers might be quite small for good climbers, and might depend more on their morphological or functional characteristics than on their age. This information can be used to focus and design interventions to improve caregiver's supervision in risk environments in order to prevent drowning and fall incidents with children.

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# 9. Epilogue

### 9.1. Main findings

In the preceding chapters we reported various experimental results pertaining to risk affordances. The actions of children and caregivers in different environments were examined.

Chapters 3, 4 and 5 addressed vertical reaching actions; chapter 5 also addressed the question of maximum step length because we sought to understand the effect of a single trial observation in adult's perception of a child's affordances in different tasks.

The findings of the vertical reachability studies revealed that adults were capable of predicting children's reachability quite accurately. However, the level of accuracy was dependent upon: i) the characteristics of the observer, ii) the characteristics of the model (i.e., child), and iii) the characteristics of the task.

The characteristics of the observer were addressed in chapter 3. Studies presented in that chapter indicated that adults were more accurate in the estimation of self vertical reachability than in the estimation of children's vertical reachability, but more accurate adults in estimating self reachability were not necessarily more precise when estimating children's reachability. The professional caregivers group had slightly more accurate perceptual estimations than the inexperienced group, suggesting that adults who had daily professional experience with different children might have undergone a perceptual learning process that led to a finer attunement to the information that specifies children's affordances.

The amount of practice necessary to better perceive children's affordance was further explored in chapter 5. The results indicated that the observation of a single trial reduced the observer's error magnitude in tasks where the first adult's estimation of the child's capabilities was poor. In chapter 3 a strong tendency for the inexperienced group observers to underestimate the older children's reachability was also observed. This bias indicates that the estimation of safe conditions by inexperienced adults might frequently be erroneous. The same underestimation tendency was verified in the vertical reaching tasks in chapter 5, but it was partially corrected after one trial observation, emphasizing the important role of perceptual experience in the estimation of children's affordances.

The characteristics of the model were thoroughly investigated in chapters 3 and 4. Studies presented in chapter 3 indicated that there was a greater overestimation tendency when evaluating children whose ratio reachability/height was smaller - that is children with more distinct proportions than those of the adults. The same problem was further investigated in chapter 4, where observers were asked to estimate three girl's height and vertical reachability. Results indicated that height was generally underestimated and reachability was generally overestimated, especially in the younger child. To our understanding, the more frequent overestimation of the younger child's reachability reveals an inability to consider children's specific body proportions when evaluating functional measures. Actually, the overestimation bias may suggest that adults perceive young children on the basis of adult's geometrical proportions.

The characteristics of the task were studied in chapters 4 and 5. In chapter 4 we concluded that the estimation errors in the absence of the child were greater than in her presence. These results support Gibson's theory of direct perception, confirming that affordances' estimation is easier when the relevant actor-environment relations are preserved (Stoffregen, Gorday, Sheng, & Flynn, 1999), but do not exclude the possible indirect perception alternative approach. In chapter 5 we also verified that some children's affordances are more difficult to predict than others. The child's action boundaries in the vertical reaching tasks (standing reach and reach-and-jump) were judged with similar levels of accuracy, but step length estimations were least accurate. This may rely on the fact that the observers in our study were least attuned to the relevant information that specify the step length affordance, as a less relevant daily action, than they were to the information that specified the most common standing reach and reach-and-jump affordances. One trial observation reduced the amount of absolute percent error in this task in about 50%. Results of our studies indicated that perceptual experience seems to play an important role in caregivers' accuracy.

Chapter 6 addressed one horizontal reaching action, the action of retrieving a toy out of the water from the swimming pool deck. The presence of toys in the water is considered a risk factor for children's drowning. The Centers for Disease Control and Prevention (CDC, 2004) emphasize that the presence of toys in the pool and surrounding area may encourage children to enter the pool area or lean over the pool and potentially fall in. Our study provided empirical evidence for that recommendation. When 1 to 4 year-olds were asked to reach a toy in a pool, they usually sat on the deck to reach it, and fell in or jumped in the water if the toy is unreachable. Sitting, squatting, crawling and ventral support were also possible solutions to retrieve the toy out of the water but occurred less frequently than falling and jumping. Task conditions (e.g., child in a bathing suit, indoor swimming pool, experimenter in the water – therefore a safety indicator for children) might have influenced the results. In addition, we studied parent's estimations of their child's behavior. We verified that most parents were cautious in the swimming pool environment and underestimated their child's maximum reachability from the pool border. Most parents also accurately predict their child's behavior when the toy is unreachable, but 11 % of parents of children that fell or jumped in the water believed their child would stay on the deck. The perceptual discrepancy may represent a problem in terms of child safety.

Chapters 7 and 8 addressed children's climbing skills, namely the climbing affordances of safety barriers for children. The findings of both studies pointed to an easy and fast crossing of common barriers that are usually adopted as architectural solutions for restraining devices. The results also evidenced differences among different types of barriers and different children.

Higher barriers with no footholds are more difficult to pass. Horizontal bar barriers do not seem appropriate to avoid children's access to risk environments. The influence of retrofitted profiles should be further investigated and seems to depend on other barrier characteristics (e.g., existence or non existence of footholds).

Children's morphological and functional variables also influence their success rate and time to cross safety barriers. As children grow older and stronger, with bigger stature, bigger arms and legs, and bigger maximum vertical reaching height, their ability to cross barriers increases while the time to do that decreases. By the age of 5 most children can successfully climb the barriers we studied. In some barriers anthropometric variables, particularly those connected to linear expressions of growth, were strong predictors of time to cross, explaining up to 62% of the differences in time to cross. In other barriers, the major predictor of time to cross was strength, a dynamic variable, which underlines the importance of considering variables other than simple static body dimensions to predict success in this sort of tasks.

Children usually adopted the safer action mode (head over waist) to cross most safety barriers, but younger children tended to adopt more unstable solutions for crossing, mainly in barriers with crossable gaps.

When children are able to cross barriers they can do it very rapidly, generally in less than 30s. Best climbers can cross a difficult barrier in just a few seconds, which emphasizes the need for an appropriate adult supervision around risk environments.

### 9.2. Methodological considerations

In the experimental work reported in this thesis we made several choices with regard to participants and experimental tasks.

The participants in our studies were children or adults that estimated children's actions. In the chapters 3, 4, 5 and 6 of the present thesis children participated as models. In those studies we sought to better comprehend questions related to the adult's estimation's of children's affordances. Consequently, we selected large sample of adults and in some cases (chapter 3) with different levels of experience in dealing with children.

In the studies were children's actions in a given environment were investigated (chapters 6, 7 and 8), we selected large samples of children within “risk-ages” for each specific risk affordance. Children most likely to drown in swimming pools in high income countries are 1 to 4 year-olds, therefore we selected that same age span for our study. The other studies that focused on the children's actions in a risk environment were the safety barriers' climbing studies. Safety barriers prevented children's access to dangerous places or heights from the moment children start having independent mobility until about 6 years of age. For that reason, participants in the studies that addressed safety barrier's climbing were pre-school children who could walk independently (i.e., 1- to 6-year-olds).

The experimental tasks selected also meant to be representative of common risk affordances for children. However, for methodological reasons, in some studies children were encouraged to do something under controlled and assisted conditions (e.g., to retrieve a toy out of the water or to cross a safety barrier), that are necessarily different from real life risk situations. Since it is not advisable to study children's reaching skills in real swimming pools with no adults around, or children's climbing skills in real balconies, the results of our studies are a natural outcome of the methods we developed in those studies, and may suffer from methodological bias.

### 9.3. Theoretical implications

The present thesis proposes an ecological approach to risk, which considers risk as a particular kind of affordance. Affordances are the possibilities for action provided for the actor by the environment (Gibson, 1979). By considering risk as a relational concept that emerges from the interaction of individual and environment, the ecological research on child safety issues must comprise the analysis of children's actions in different environments. That was the approach presented in this thesis.

Affordances are specific to each individual, what constitutes a certain affordance for one child might not constitute the same affordance for another, as we have seen in the previous chapters. The same safety barrier might afford climbing and crossing for taller and older children but not for younger and shorter children. Affordances are not mediated via cognitive representations and they can be directly perceived. However, the process of knowing what specifies an affordance might be long. Children make errors in judging risk affordances and that happens when they are not attuned to the relevant environmental properties in order to guide their behavior. A child that climbs a safety barrier and crosses it passing with the head and waist at the same level or with the head under the waist, limiting his/her control of balance and movement and risking to fall, is probably still learning how to be attuned to relevant information for crossing that barrier. Children with enhanced motor control and skill usually cross safety barriers passing with the head over the waist. A child that leans over the swimming pool to reach for a toy but loses balance and falls in the water, is probably still learning to be attuned to the proprioceptive and visual information that specifies his/her reachability limits under an unstable posture. While children are not attuned to the relevant informational variables that specify a given affordance, their ability to perceive what is possible and what is not possible is impaired. For that reason, caregivers' role in constraining risky affordances for children, by supervising their behaviors and by structuring the environment they move in, is of fundamental importance.

The caregiver's estimation of a child's affordances is an important issue in terms of child safety. This issue was addressed in chapters 3 to 6 of the present thesis and might be framed in the question of the perception of other people's affordances (Mark, 2007; Rochat, 1995; Stoffregen, Gorday, Sheng, & Flynn, 1999). Our studies confirmed that the information that specifies affordances, mainly body-scaled affordances, is public, being available not only to the actor but also to an observer. The perception of other people's affordances is also direct. In chapter 6 we verified that when the estimation was made in the absence of the child, estimation errors were greater, meaning that when the relevant actor-environment relations were not present during estimation, observers had to rely on their visual memory of the child's dimensions and, consequently, their accuracy diminished. Estimation errors were also greater in younger children and in some tasks. The fact that adult's were least accurate while evaluating younger children probably reveals an inability to consider children's specific body proportions, and indicates that adults might not be attuned to the environmental information that specifies children's reachability. The results suggest that the process of attunement might be more difficult in more atypical models. Likewise, the fact that some actions (e.g., step length) are more difficult to predict than others is probably a difficulty of attunement to the right informational variables in less familiar tasks. The possibility of observing the child performing a less familiar task seems to be fundamental to refine the observer's accuracy. In chapter 8 we verified that one trial observation increased the perceivers' accuracy in about 50% in tasks where their first estimation was poor.

### 9.4. Practical implications

Many of the practical implications of the present thesis were underlined in the previous chapters. The most important ones are presented next.

The studies that investigated adults' perception of children's affordances emphasized the importance of adult's supervision around risk environments. Adult's can perceive children's affordances with reasonable accuracy and that accuracy might be improved through perceptual learning. This information can be used to design interventions to improve caregiver's supervision in risk environments in order to prevent accidents with children.

The study of children's reachability in the swimming pool evidenced the importance of adult supervision around water environments and underlined the need to remove toys from the pool and surrounding area immediately after use. The removal of obstacles that might limit visual information of the deck areas was also recommended to ensure an efficient parental supervision around water environments.

The studies that addressed children's climbing of safety barriers underlined that safety barriers are not absolutely preventive tools; they are just time delaying devices that can give the opportunity for adult intervention. Horizontal bar barriers were considered inefficient to prevent children's access to dangerous places, and a re-examination of the international regulations for barriers that state the dimension of 0.18 m in gaps ≥ 0.45 m above the floor was recommended.

### 9.5. Future research

Some questions were raised during the previous chapters that might constitute interesting topics for further research.

Studies that addressed the issue of adult's perception of children's vertical reachability raise two important queries for future research. The first is related to adult's greater difficulty in perceiving the younger children's specific body proportions. The question of attunement while estimating affordances for more atypical models is undoubtedly important for parents and caregivers of young children. The second question is related to the improvements verified in perceivers' accuracy after the observation of a single trial. The problem of the amount of practice needed for achieving a more permanent process of perceptual learning should be investigated in future studies. The effects of repeated observation on the estimation accuracy of affordances for other persons deserve deeper investigation.

In chapter 6 we verified that anthropometric characteristics, walking experience and swimming program experience were poor predictors of parents' estimations of their children's maximum reachability in the swimming pool task. The analysis of the influence of other variables (e.g. temperamental characteristics), in parent's estimations of children's capabilities in risk environments deserves further investigation. Future studies might also address the task of retrieving a toy from a swimming pool but under different environmental and task constraints (e.g., child dressed, cold water). The frequency of children that would jump or fall in the water, or even the frequency of the sitting action mode used to retrieve the toy out of the water, would probably be smaller.

In chapters 7 and 8 we verified that children can easily and rapidly cross some of the common barriers that are usually adopted as architectural solutions for restraining devices. The influence of retrofitted profiles should be further investigated since studies had contradictory results relative to this barrier characteristic. In the first study, retrofitted profiles increased the restraining capacity of barriers with footholds but decreased it in solid panel barriers, probably because they offer extra grasping points. However, this decrease was not confirmed in the second study. The study of children's climbing skills in vertical bar barriers might also be addressed by further investigations.

**9.6. General conclusion**

The present thesis underlines the importance of adult supervision around different risk environments. Children can act in creative ways to reach their goals. The curiosity and need for exploration allied with children's ever growing action capabilities might turn a difficult obstacle or situation (e.g. passing a safety barrier or reaching a toy in a swimming pool) into a defying challenge. Adult's can perceive risk affordances for children with reasonable accuracy. There are good indications that accuracy in perceiving children's affordances can be improved through perceptual training, which will help caregiver's to be attuned to the information that specifies children's affordances. Subsequently, caregivers have the difficult task of helping children to become themselves attuned to the worthwhile affordances in the environment in order to help their discovery process in a challenging but safe way.

### 9.7. References

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